TETRA TECH

October 26, 2015

Mr. James Johnson
On-Scene Coordinator
U.S. Environmental Protection Agency, Region 7
11201 Renner Boulevard
Lenexa, Kansas 66219

Subject: **Final Data Summary of Baseline Off-site Air Monitoring Via Sampling for Volatile Organic Compounds and Hydrogen Sulfide by Application of Passive/Diffusive Sampling Methods**
West Lake Landfill Site, Bridgeton, Missouri
CERCLIS ID: MOD079900932
EPA Region 7, START 4, Contract No. EP-S7-13-06, Task Order No. 0058
Task Monitor: James Johnson, On-Scene Coordinator

Dear Mr. Johnson:

Tetra Tech, Inc. is submitting the attached Final Data Summary Report regarding volatile organic compound and hydrogen sulfide sampling by use of passive/diffusive samplers during air monitoring at locations off site of the West Lake Landfill site (WLLS) in Bridgeton, Missouri. This sampling occurred during a baseline period, from December 18, 2014, through May 28, 2015. If you have any questions or comments, please contact me at (816) 412-1775.

Sincerely,

Robert Monnig, PE
START Project Manager

Ted Faile, PG, CHMM
START Program Manager

Enclosures

cc: Debra Dorsey, START Project Officer (cover letter only)

X9025.14.0058.000

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WLLFOIA4312 - 015 - 0154822

FINAL DATA SUMMARY OF BASELINE OFF-SITE AIR MONITORING VIA SAMPLING FOR VOLATILE ORGANIC COMPOUNDS AND HYDROGEN SULFIDE BY APPLICATION OF PASSIVE/DIFFUSIVE SAMPLING METHODS

WEST LAKE LANDFILL SITE
BRIDGETON, MISSOURI
CERCLIS ID: MOD079900932

Superfund Technical Assessment and Response Team (START) 4
Contract No. EP-S7-13-06, Task Order No. 0058

Prepared For:

U.S. Environmental Protection Agency
Region 7
Superfund Division
11201 Renner Blvd.
Lenexa, Kansas 66219

October 26, 2015

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EXECUTIVE SUMMARY

The Tetra Tech, Inc. (Tetra Tech) Superfund Technical Assessment and Response Team (START) was tasked by the U.S. Environmental Protection Agency (EPA) to assist with baseline air monitoring at off-site locations around the West Lake Landfill site (WLLS) in Bridgeton, Missouri. This report summarizes results of sampling air for volatile organic compounds (VOC) and hydrogen sulfide (H_2S) by use of passive/diffusive samplers during the baseline period, from December 18, 2014, through May 28, 2015. Baseline sampling via passive/diffusive methods was initiated during the baseline monitoring period after stakeholders had identified the sampling methodology for possible use during construction of the isolation barrier.

The baseline period air monitoring occurred at the following off-site monitoring stations according to the EPA-approved quality assurance project plan (QAPP):

1. **Station 1** – Robertson Fire Protection District Station 2, 3820 Taussig Rd., Bridgeton, Missouri
2. **Station 2** – Pattonville Fire Department District, 13900 St Charles Rock Rd., Bridgeton, Missouri
3. **Station 3** – Pattonville Fire Department District Station 2, 3365 McKelvey Rd., Bridgeton, Missouri
4. **Station 4** – Spanish Village Park, 12827 Spanish Village Dr., Bridgeton, Missouri
5. **Station 5** – St. Charles Fire Department Station #2, 1550 S. Main St., St. Charles, Missouri.

The Station 1 through 4 locations were selected primarily for their positions near and around WLLS (approximately 0.3 to 1 mile from WLLS, in various directions from WLLS). Station 5, designated as a reference (or background) station, is farther away from WLLS than the other stations, but still within the general vicinity so as to be representative of the North St. Louis County and eastern St. Charles County area.

Data from the passive/diffusive samplers collected from December 18, 2014, through May 28, 2015, were evaluated for differences in measured concentrations among the air monitoring stations off site of the WLLS. In addition, VOC results obtained by use of the passive/diffusive samplers were compared to VOC results previously obtained via 24-hour Summa® canister sampling at the WLLS air monitoring stations. The following describes the findings:

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- VOC concentrations detected at the five WLLS air monitoring stations via passive/diffusive sampling are within the concentration ranges previously detected at the air monitoring stations via 24-hour Summa canister sampling. Previous examination of 24-hour VOC concentrations detected at the five WLLS air monitoring stations revealed concentrations typical for an outdoor urban environment (see Tetra Tech 2015d). Thus, VOC concentrations detected at the five WLLS air monitoring stations via passive/diffusive sampling also appear typical for an outdoor urban environment.

- Examination of data plots and statistical testing for differences in VOC concentrations detected via passive/diffusive sampling among the five air monitoring stations suggests tendency for detection of TCE at higher concentrations at Station 2 than at the other stations (Stations 1, 3, 4, and 5). A similar result was obtained from statistical testing of TCE data obtained via 24-hour sampling with Summa canisters at the five air monitoring stations. Although differences were detected among the stations, TCE concentrations at the five WLLS monitoring stations (including Station 2) were found comparable to 24-hour TCE concentrations EPA has detected at other urban areas via the National Air Toxics Treads Stations (NATTS) air monitoring program.

- No statistically significant differences in H_2S concentrations were found among the five WLLS air monitoring stations, and the concentrations were consistent with typical H_2S concentrations within outdoor urban environments.

Overall, the VOC and H_2S measurements obtained via passive/diffusive sampling at the off-site monitoring stations appear typical for outdoor urban measurements.

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1.0 INTRODUCTION

The Tetra Tech, Inc. (Tetra Tech) Superfund Technical Assessment and Response Team (START) was tasked by the U.S. Environmental Protection Agency (EPA) to assist with baseline monitoring at offsite locations around the West Lake Landfill site (WLLS) in Bridgeton, Missouri. This report summarizes results from sampling air for volatile organic compounds (VOC) and hydrogen sulfide (H_2S) by use of passive/diffusive samplers from December 18, 2014, through May 28, 2015. Baseline sampling via passive/diffusive methods was initiated during the baseline monitoring period after stakeholders had identified the sampling methodology for possible use during construction of the isolation barrier.

For the overall baseline monitoring campaign, START's tasks included: (1) assembling and maintaining a network of off-site air monitoring stations with instrumentation and sampling devices to measure parameters of concern, (2) collecting samples and coordinating laboratory analysis, (3) assisting EPA with data acquisition and management, (4) documenting off-site air monitoring efforts, and (5) validating/verifying initial screening of the data. The objective of this report is to present a summary of VOCs and H_2S data acquired by use of passive/diffusive samplers, including findings related to data validation, verification, and usability. Site figures are in Appendix A. Tabulated sampling results are in Appendix B. Time-series plots of the data are in Appendix C. Statistical analyses are in Appendices D and E. Manufacturer datasheets regarding the sampling equipment are included in Appendix F.

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2.0 PROBLEM DEFINITION, BACKGROUND, AND SITE DESCRIPTION

EPA conducted air monitoring at locations off site of WLLS during a pre-construction, baseline period prior to initiation of construction of a planned isolation barrier at WLLS. Air monitoring during the baseline period will provide data for use to (1) evaluate pre-construction concentrations of chemical and radiological parameters of potential concern in outdoor air, and (2) optimize the sampling and monitoring plan for off-site air monitoring to occur during construction of the isolation barrier. During barrier construction, air monitoring will occur to address concerns that construction operations at WLLS could impact human health and the environment via release to ambient air of solid waste landfill gases of concern or of particulates with radiologically-impacted materials (RIM).

West Lake Landfill is an approximately 200-acre property including several closed solid waste landfill units that accepted wastes for landfilling from the 1940s or 1950s through 2004, plus a solid waste transfer station, a concrete plant, and an asphalt batch plant. WLLS is at 13570 St. Charles Rock Road in Bridgeton, St. Louis County, Missouri, approximately 1 mile north of the intersection of Interstate 70 and Interstate 270 (see Appendix A, Figure 1). WLLS was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the late 1940s or early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, approximately 8,700 tons of leached barium sulfate residues (a remnant from the Manhattan Engineer District/Atomic Energy Commission project) was reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, Missouri, transported to the WLLS, and used as daily or intermediate cover material. In December 2004, the Bridgeton Sanitary Landfill—the last landfill unit to receive solid waste—stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce potential for birds to interfere with Lambert Field International Airport operations. In December 2010, Bridgeton Landfill detected changes—elevated temperatures and elevated carbon monoxide levels—in its landfill gas extraction system operating at the South Quarry of the Bridgeton Sanitary Landfill portion of the site (a landfill portion not associated with known RIM). Further investigation indicated that the South Quarry Pit landfill was undergoing an exothermic subsurface smoldering event (SSE). In 2013, potentially responsible parties committed to constructing an isolation barrier that would separate the Bridgeton Landfill undergoing the SSE from the RIM-containing portions of WLLS (EPA 2014).

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3.0 SAMPLING STRATEGY AND METHODOLOGY

In April/May 2014, EPA and START began baseline monitoring and sampling for the chemical and radiological parameters of concern at five off-site monitoring stations. Baseline sampling for VOCs and H_2S via passive/diffusive methods (the subject of this report) began in December 2014 after the sampling methodology had been identified for possible use during the isolation barrier construction. Sampling occurred at the following monitoring stations (see Appendix A, Figure 1):

1. **Station 1** – Robertson Fire Protection District Station 2, 3820 Taussig Rd., Bridgeton, Missouri
2. **Station 2** – Pattonville Fire Department District, 13900 St Charles Rock Rd., Bridgeton, Missouri
3. **Station 3** – Pattonville Fire Department District Station 2, 3365 McKelvey Rd., Bridgeton, Missouri
4. **Station 4** – Spanish Village Park, 12827 Spanish Village Dr., Bridgeton, Missouri
5. **Station 5** – St. Charles Fire Department Station #2, 1550 S. Main St., St. Charles, Missouri.

The Station 1 through 4 locations were selected primarily for their positions near and around WLLS (approximately 0.3 to 1 mile from WLLS, in various directions from WLLS). Station 5 was designated as a reference (or background) station, and its location was selected according to the criterion that it be frequently upwind of WLLS and farther away from WLLS than the other stations, but still within the general vicinity so as to be representative of the North St. Louis County and eastern St. Charles County area (see wind rose in Appendix A, Figure 1).

VOCs were identified as a parameter of potential concern in the Quality Assurance Project Plan (QAPP) (Tetra Tech 2014) based on historical information regarding the site and program experience with similar types of sites. Sampling for VOCs during the baseline monitoring period occurred primarily by use of Summa® canisters (collected over a 24-hour period) and laboratory analysis via EPA Method TO-15. Sampling by use of Summa canisters occurred weekly at the air monitoring stations from May 8 to December 17, 2014, and the resulting data were summarized and evaluated by Tetra Tech (2015d). The report herein summarizes VOC sampling by use of passive/diffusive samplers that began in December 2014 after stakeholders had identified the sampling methodology for possible use during isolation barrier construction. This sampling occurred via deployment of Radiello® brand passive/diffusive samplers fitted with activated charcoal adsorbent cartridges. The cartridges were generally deployed at each of the five

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monitoring stations continuously for sampling durations of approximately 7 days[1]. At the end of the sampling duration, the deployed cartridges were collected, and a new sampling deployment was initiated with new cartridges. The Radiello cartridges for VOC sampling were shipped to Pace Analytical Laboratory (Pace) in Lenexa, Kansas, for analysis via Method EPA TO-17 modified for analysis of the Radiello cartridges.

H_2S, another parameter of potential concern identified in the QAPP (Tetra Tech 2014), was also sampled by use of Radiello cartridges concurrently with the VOC Radiello sampling at the five air monitoring stations. Radiello samplers deployed for H_2S sampling were fitted with adsorbent cartridges containing zinc acetate. These cartridges were shipped to ALS Laboratory in Simi Valley, California, for analysis via an extraction and colorimetric analysis specified by the Radiello cartridge manufacturer.

Baseline VOC and H_2S monitoring via passive/diffusive samplers ended on March 13, 2015, at Stations 1, 2, 3, and 5, and on May 28, 2015, at Station 4. This report summarizes all VOC and H_2S monitoring via passive/diffusive samplers during the baseline period.

[1] The Radiello cartridges collected on January 19, 2015, were deployed for 14 days to assess for any significant differences in measured analyte concentrations (or detection limits) from those obtained during a 7-day deployment (no significant differences were observed).

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4.0 SUMMARY AND EVALUATION OF VOC AND H_2S RESULTS

The following sections summarize VOC and H_2S results from Radiello passive/diffusive samplers during the baseline monitoring period, including time series plots and results of statistical analyses.

4.1 DATA VALIDATION, VERIFICATION, AND USABILITY

As laboratory analytical reports are received for the analyses, START reviews and qualifies the data according to the EPA *Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review* guidance document (EPA 2008). This is standard practice for EPA data. A data validation report is appended to each analytical laboratory report, and is included in each data deliverable package (see Tetra Tech 2015a, b, c, d, f, g). Qualifications to the data from START's review are indicated by qualifier flags that accompany the data presented therein. Overall, review of the laboratory analytical data packages indicated that quality of the VOC and H_2S data was acceptable and usable as qualified for the intended purposes of the data.

On March 19, 2015, Pace notified Tetra Tech that its chemists had identified benzene and toluene contamination in the sorbent media that appeared to originate from the sorbent media supplied by the manufacturer. For the samples affected, Pace did not report benzene or toluene concentrations. The affected samples were generally those collected between January 28 and April 3, 2015. Because the potentially affected data (benzene and toluene concentrations) were not reported by the laboratory, no specific qualifications were assigned via START's data validation/verification.

4.2 RESULTS AND EVALUATION

The following describes results of sampling for VOCs and H_2S during the baseline period from December 18, 2014, through May 28, 2015, by use of passive/diffusive Radiello samplers.

4.2.1 Summary of Results

Appendix B presents the Radiello sampling results and summary statistics for VOCs (see Tables B-1 through B-14) and H_2S (see Table B-15). Appendix C presents a time-series plot for each VOC (see Exhibits C-1 through C-14) and for H_2S (see Exhibit C-15). As discussed in Section 4.2.3, the time-series

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plots for the VOCs also show, for comparison, VOC results obtained via 24-hour sampling by use of Summa canisters[2].

4.2.2 Comparison of Results Among Off-site Monitoring Stations

Differences in measured concentrations of VOCs and H_2S among the air monitoring stations are evaluated and described in this section so that data users can be aware of those differences when using the pre-construction baseline data. Comparisons of measured concentrations among the air monitoring stations proceeded via statistical testing. Results obtained by use of Radiello cartridges were compared (comparisons of Summa VOC results among the stations appear in Tetra Tech 2015e). The following describes the evaluations.

Friedman Statistical Test

The Friedman test was used to test for differences in VOCs and H_2S concentrations among the five monitoring stations. The Friedman test compares multiple treatments (such as the multiple monitoring locations) while accounting for related data (such as cluster or data from week to week or changes in detection limits from week to week). The Friedman test was selected in particular because it is a non-parametric statistical (rank- or percentiles-based) test that can accommodate non-detect (or "less than") results found in the data, and also because detection limits tended to vary from week to week. Before performance of the test, the data were prepared for the test as recommended in *Statistics for Censored Environmental Data Using Minitab® and R* (Helsel 2012). That is, for each analyte, the data were censored at the highest reporting limit for the particular sampling period by assigning all values below the highest reporting limit (including all non-detects and any reported value less than the highest reporting limit) a low and arbitrary value; the value "-1" was used. The statistical software package R was used to conduct the Friedman tests. Results of the analysis suggested statistically significant differences in concentrations of one VOC analyte among the five monitoring stations:

- **Trichloroethene (TCE):** The Friedman test detected differences among Stations 1-5, but a post-hoc analysis was inconclusive regarding pair-wise, station-to-station comparisons. A plot of the data suggests Station 2 tended to have higher measurements than the other stations (*p-value* = 0.02623).

[2] *Data Summary of Ongoing Baseline Off-Site Air Monitoring, Volatile Organic Compounds by Test Method TO-15* (Tetra Tech 2015e) presents an evaluation of VOC results obtained via 24-hour sampling by use of Summa canisters.

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The analysis found no statistically significant difference in H_2S concentrations among the five monitoring stations. A summary of the Friedman test results is in Appendix D, Table D-1. Output of the Friedman test analyses via the software package R is in Appendix E.

Statistical analysis applied to VOC results obtained via 24-hour sampling by use of Summa canisters also found statistically significant differences in TCE concentrations among the five stations (the test indicated that measurements of concentration at Station 2 tended to be higher than at Stations 1, 3, and 4) (see Tetra Tech 2015e).

4.2.3 Comparison of VOC Results from Radiello and Summa Canister Methods

To compare passive/diffusive Radiello sampling data with data from previous 24-hour sampling by use of Summa canisters[3], both data sets were plotted in the Appendix C plots (isopropylbenzene, methyl-tert-butyl ether, and *trans*-1,2-dichloroethene were reported only in the Radiello analysis). Notably, for those VOCs concentrations measured by both methods, Radiello results were within the range of concentrations measured by use of Summa canisters.

4.2.4 Comparison of H_2S Results to Typical Ambient Concentrations

Reported H_2S concentrations ranged from 0.16 to 0.64 micrograms per cubic meter ($\mu g/m^3$) (approximately 0.12 to 0.46 parts per billion [ppb]). The Agency for Toxic Substances and Disease Registry (ATSDR) reports that ambient air concentrations of H_2S from natural sources range between 0.11 and 0.33 ppb, and that concentrations of H_2S in urban areas are generally less than 1 ppb (ATSDR 2014). Thus, H_2S results from the five off-site monitoring stations appear typical for outdoor urban measurements.

[3] *Data Summary of Ongoing Baseline Off-Site Air Monitoring, Volatile Organic Compounds by Test Method TO-15* (Tetra Tech 2015e) presents an evaluation of VOC results obtained via 24-hour sampling by use of Summa canisters.

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5.0 ANALYSIS OF RESULTS

As discussed above, examination of data plots and statistical testing for differences in concentrations among the five air monitoring stations suggests a tendency for measurements of TCE concentration to be higher at Station 2 than at the other stations 1, 3, 4, and 5. A similar result was obtained from statistical testing of the TCE data obtained via 24-hour sampling by use of Summa canisters at the five air monitoring stations; however, the 24-hour TCE concentrations were found comparable to 24-hour TCE concentrations EPA had detected at other urban areas under the National Air Toxics Treads Stations (NATTS) air monitoring program (see Tetra Tech 2015e). TCE concentrations detected via Radiello sampling are within the range of 24-hour concentrations previously detected at WLLS air monitoring stations via 24-hour Summa sampling (see Appendix C, Exhibit C-13), and are thus also comparable to concentrations detected in other urban areas.

TCE is a common industrial solvent that frequently appears in groundwater contaminant plumes at cleanup sites from historical use and improper disposal. Given the chemical properties of TCE, if found in the buried waste at WLLS, TCE likely would be found in the groundwater and released to the air. However, EPA reviewed groundwater data from WLLS and found no indication of presence of TCE. Further, if TCE were found in the buried waste at WLLS, it likely would be detected in the leachate resulting from moisture percolating through the buried waste material. However, TCE was also not detected in leachate samples collected at WLLS prior to treatment. Thus, TCE does not appear to be present in the buried waste at WLLS, and, by inference, the detections in ambient air are not believed to have resulted from releases of this VOC from WLLS. Moreover, EPA's examination of reports of air emissions from various industrial facilities in the area revealed presence of other possible sources of TCE.

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6.0 SUMMARY OF OBSERVATIONS

VOCs and H_2S sampling via 1- and 2-week deployments of passive/diffusive samplers began in December 2014 as part of baseline off-site air monitoring at five air monitoring stations off site of WLLS. This report summarizes and evaluates data from the passive/diffusive samplers obtained from December 18, 2014, through May 28, 2015. Differences in measured concentrations among the air monitoring stations off site of the WLLS were evaluated. In addition, VOC results obtained by use of the passive/diffusive samplers were compared to VOC results previously obtained via 24-hour Summa canister sampling at the WLLS air monitoring stations. The following describes the findings.

- VOC concentrations detected at the five WLLS air monitoring stations via passive/diffusive sampling are within the concentration ranges previously detected at the air monitoring stations via 24-hour Summa canister sampling. Previous examination of 24-hour VOC concentrations detected at the five WLLS air monitoring stations revealed concentrations typical for an outdoor urban environment (see Tetra Tech 2015e). Thus, VOC concentrations detected at the five WLLS air monitoring stations via passive/diffusive sampling also appear typical for an outdoor urban environment.

- Examination of data plots and statistical testing for differences in VOC concentrations detected via passive/diffusive sampling among the five air monitoring stations suggests tendency for detection of TCE at higher concentrations at Station 2 than at the other stations (Stations 1, 3, 4, and 5). A similar result was obtained from statistical testing of TCE data obtained via 24-hour sampling with Summa canisters at the five air monitoring stations. Although differences were detected among the stations, TCE concentrations at the five WLLS monitoring stations (including Station 2) were found comparable to 24-hour TCE concentrations EPA had detected at other urban areas via the National Air Toxics Treads Stations (NATTS) air monitoring program.

- No statistically significant differences in H_2S concentrations were found among the five WLLS air monitoring stations, and the concentrations were consistent with typical H_2S concentrations within outdoor urban environments.

Overall, the VOCs and H_2S measurements obtained via passive/diffusive sampling at the off-site monitoring stations appear typical for outdoor urban measurements.

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7.0 REFERENCES

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Helsel, Dennis R. 2012. *Statistics for Censored Environmental Data Using Minitab® and R.* Second Edition. John Wiley & Sons, Inc.

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Tetra Tech. 2015b. Data Deliverable Package 08, West Lake Landfill Site, Bridgeton, Missouri. March 10.

Tetra Tech. 2015c. Data Deliverable Package 09, West Lake Landfill Site, Bridgeton, Missouri. March 20.

Tetra Tech. 2015d. Data Deliverable Package 10, West Lake Landfill Site, Bridgeton, Missouri. April 27.

Tetra Tech. 2015e. Data Summary of Ongoing Baseline Off-Site Air Monitoring for Volatile Organic Compounds by Test Method TO-15, West Lake Landfill Site, Bridgeton, Missouri. May 26.

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Tetra Tech. 2015g. Data Deliverable Package 13, West Lake Landfill Site, Bridgeton, Missouri. October 2, 2015.

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APPENDIX A

FIGURES

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Station 1 - Robertson Fire Protection District Station 2
(0.27 miles from West Lake Landfill)

Station 2 - Pattonville Fire Protection District Headquarters
(0.60 miles from West Lake Landfill)

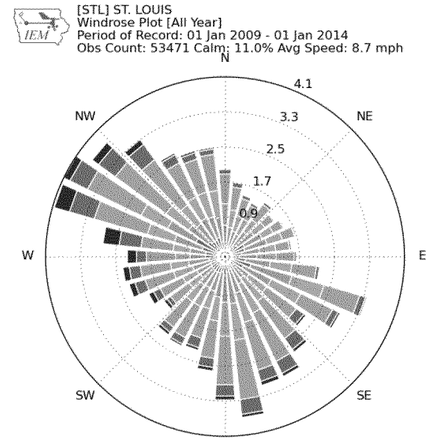
Station 5 - St. Charles Fire Department Station 2
(2.34 miles from West Lake Landfill)

Station 4 - Spanish Village Park
(0.42 miles from West Lake Landfill)

Station 3 - Pattonville Fire Department Station 2
(1.05 miles from West Lake Landfill)

Legend

- Off-site air monitoring station
- West Lake Landfill Site Operable Unit 1 (radiological area)
- Bridgeton Landfill



N

0 1,000 2,000

Feet

Source: ArcGIS Online Aerial Imagery, 2013; Iowa State University of Science and Technology, 2015

West Lake Landfill
Bridgeton, Missouri

Figure 1

Off-Site Air Monitoring Stations

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Date: 10/1/2015 Drawn By: Bill Spiking Project No: X9025.14.0058.000

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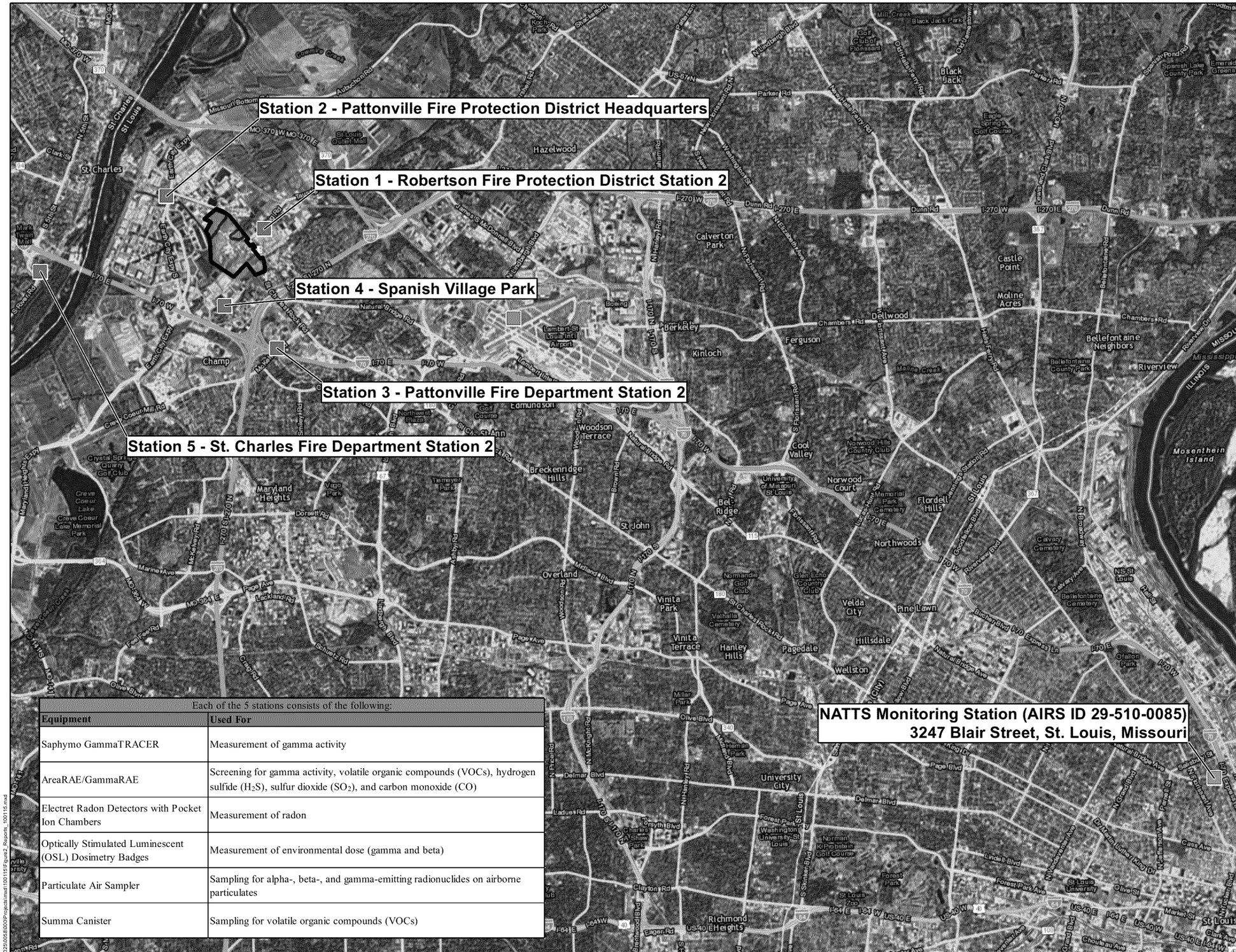


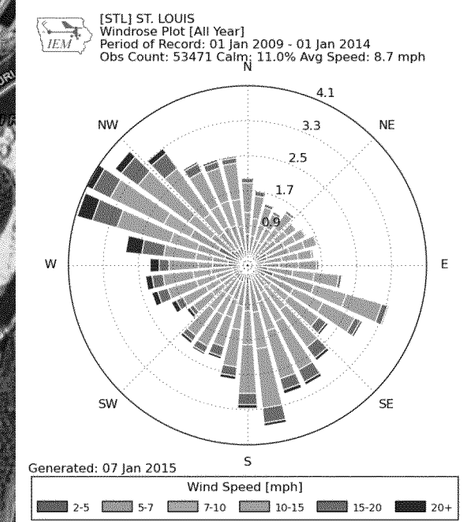
Each of the 5 stations consists of the following:

Equipment	Used For
Saphymo GammaTRACER	Measurement of gamma activity
AreaRAE/GammaRAE	Screening for gamma activity, volatile organic compounds (VOCs), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), and carbon monoxide (CO)
Electret Radon Detectors with Pocket Ion Chambers	Measurement of radon
Optically Stimulated Luminescent (OSL) Dosimetry Badges	Measurement of environmental dose (gamma and beta)
Particulate Air Sampler	Sampling for alpha-, beta-, and gamma-emitting radionuclides on airborne particulates
Summa Canister	Sampling for volatile organic compounds (VOCs)

Legend

- Lambert St. Louis International Airport Metar Station
- NATTS monitoring station
- Off-site air monitoring station
- Bridgeton Landfill
- West Lake Landfill Site Operable Unit 1 (radiological area)

NATTS National Air Toxics Trends Station



N

0 3,500 7,000

Feet

Source: ArcGIS Online Aerial Imagery, 2013; Iowa State Univerity of Science and Technology, 2015

West Lake Landfill
Bridgeton, Missouri

Figure 2

Location of St. Louis NATTS Air Monitoring Station

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Date: 10/1/2015 Drawn By: Gustavo Orozco Project No: X9025.14.0058.000

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APPENDIX B

TABULATED RESULTS

Table B-1
1,2,4-Trimethylbenzene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0034)	ND (0.0034)	ND (0.0034)	ND (0.0034)/ND (0.0034)	ND (0.0034)
12/27/2014	ND (0.0032)	ND (0.0032)	ND (0.0032)	ND (0.0032)/ND (0.0032)	ND (0.0032)
1/5/2015	ND (0.003)	ND (0.003)	ND (0.003)	ND (0.003)/ND (0.003)	ND (0.003)
1/19/2015	ND (0.002)	ND (0.002)	ND (0.002)	ND (0.002)/ND (0.002)	ND (0.002)
1/28/2015	0.26	0.27	0.32	0.350 /0.250	0.45
2/4/2015	ND (10.9)	ND (10.9)	ND (10.8)	ND (10.9)/ND (10.9)	ND (10.8)
2/13/2015	0.150 /0.075	0.14	0.18	0.13	0.17
2/20/2015	U	U	U	U/U	U
2/27/2015	U	U	U	U/U	U
3/6/2015	0.21	U	U	U/ND (0.095)	U
3/13/2015	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)/ND (1.0)	ND (1.0)
3/20/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
3/27/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
4/3/2015	NS	NS	NS	U/U	NS
4/10/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
4/17/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
4/24/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
5/1/2015	NS	NS	NS	ND (0.004)/ND (0.004)	NS
5/8/2015	NS	NS	NS	ND (0.0099)/ND (0.0099)	NS
5/15/2015	NS	NS	NS	U/U	NS
5/21/2015	NS	NS	NS	ND (0.011)/ND (0.011)	NS
5/28/2015	NS	NS	NS	ND (0.01)/ND (0.01)	NS
No. of Detects	**4**	**2**	**2**	**3**	**2**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.075**	**0.14**	**0.18**	**0.13**	**0.17**
Median	**0.18**	**0.205**	**0.25**	**0.25**	**0.31**
Maximum	**0.26**	**0.27**	**0.32**	**0.35**	**0.45**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

Table B-2
1,3,5-Trimethylbenzene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0034)	ND (0.0034)	ND (0.0034)	ND (0.0034)/ND (0.0034)	ND (0.0034)
12/27/2014	ND (0.0032)	ND (0.0032)	ND (0.0032)	ND (0.0032)/ND (0.0032)	ND (0.0032)
1/5/2015	ND (0.003)	ND (0.003)	ND (0.003)	ND (0.003)/ND (0.003)	ND (0.003)
1/19/2015	ND (0.002)	ND (0.002)	ND (0.002)	ND (0.002)/ND (0.002)	ND (0.002)
1/28/2015	0.11	0.1	0.11	0.100 /0.088	0.13
2/4/2015	ND (10.9)	ND (10.9)	ND (10.8)	ND (10.9)/ND (10.9)	ND (10.8)
2/13/2015	0.052 /0.032	0.046	0.054	0.046	0.056
2/20/2015	U	U	U	ND (0.041)/U	U
2/27/2015	ND (0.095)	ND (0.095)	ND (0.095)	0.110 /ND (0.095)	ND (0.095)
3/6/2015	ND (0.095)	ND (0.095)	ND (0.095)	ND (0.095)/ND (0.095)	ND (0.095)
3/13/2015	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)/ND (1.0)	ND (1.0)
3/20/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
3/27/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
4/3/2015	NS	NS	NS	U/U	NS
4/10/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
4/17/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
4/24/2015	NS	NS	NS	ND (0.0039)/ND (0.0039)	NS
5/1/2015	NS	NS	NS	ND (0.004)/ND (0.004)	NS
5/8/2015	NS	NS	NS	ND (0.0099)/ND (0.0099)	NS
5/15/2015	NS	NS	NS	U/U	NS
5/21/2015	NS	NS	NS	ND (0.011)/ND (0.011)	NS
5/28/2015	NS	NS	NS	ND (0.01)/ND (0.01)	NS
No. of Detects	**3**	**2**	**2**	**4**	**2**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.032**	**0.046**	**0.054**	**0.046**	**0.056**
Median	**0.052**	**0.073**	**0.082**	**0.094**	**0.093**
Maximum	**0.11**	**0.1**	**0.11**	**0.11**	**0.13**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

Table B-3
Benzene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0021)	ND (0.0021)	ND (0.0021)	ND (0.0021)/ND (0.0021)	ND (0.0021)
12/27/2014	ND (0.002)	ND (0.002)	ND (0.002)	ND (0.002)/ND (0.002)	ND (0.002)
1/5/2015	ND (0.0019)	ND (0.0019)	ND (0.0019)	ND (0.0019)/ND (0.0019)	ND (0.0019)
1/19/2015	ND (0.0012)	ND (0.0012)	ND (0.0012)	ND (0.0012)/ND (0.0012)	ND (0.0012)
2/20/2015	NR	NR	U	U	NR
3/20/2015	NS	NS	NS	0.700 /0.670	NS
4/10/2015	NS	NS	NS	ND (0.0024)/ND (0.0024)	NS
4/17/2015	NS	NS	NS	ND (0.0024)/ND (0.0024)	NS
4/24/2015	NS	NS	NS	ND (0.0024)/ND (0.0024)	NS
5/1/2015	NS	NS	NS	ND (0.0025)/ND (0.0025)	NS
5/8/2015	NS	NS	NS	ND (0.0062)/ND (0.0062)	NS
5/15/2015	NS	NS	NS	0.450 /0.410	NS
5/21/2015	NS	NS	NS	ND (0.0072)/ND (0.0072)	NS
5/28/2015	NS	NS	NS	ND (0.0063)/ND (0.0063)	NS
No. of Detects	**0**	**0**	**0**	**4**	**0**
No. of Samples	**4**	**4**	**5**	**28**	**4**
Minimum	**NA**	**NA**	**NA**	**0.41**	**NA**
Median	**NA**	**NA**	**NA**	**0.56**	**NA**
Maximum	**NA**	**NA**	**NA**	**0.7**	**NA**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

NA	not applicable
ND ( )	not detected (method detection limit)
NR	not reported by laboratory
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-4
cis-1,2-Dichloroethene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0022)	ND (0.0022)	ND (0.0022)	ND (0.0022)/ND (0.0022)	ND (0.0022)
12/27/2014	ND (0.0021)	ND (0.0021)	ND (0.0021)	ND (0.0021)/ND (0.0021)	ND (0.0021)
1/5/2015	ND (0.002)	ND (0.002)	ND (0.002)	ND (0.002)/ND (0.002)	ND (0.002)
1/19/2015	ND (0.0013)	ND (0.0013)	ND (0.0013)	ND (0.0013)/ND (0.0013)	ND (0.0013)
1/28/2015	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)/ND (0.0059)	ND (0.0059)
2/4/2015	ND (3.7)	ND (3.7)	ND (3.7)	ND (3.7)/ND (3.7)	ND (3.7)
2/13/2015	ND (0.0059)/ND (0.0071)	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)
2/20/2015	ND (0.0076)	ND (0.0076)	U	ND (0.032)/U	ND (0.0076)
2/27/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/6/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	ND (0.0076)/ND (0.0076)	NS
4/10/2015	NS	NS	NS	ND (0.0064)/ND (0.0064)	NS
4/17/2015	NS	NS	NS	ND (0.0064)/ND (0.0064)	NS
4/24/2015	NS	NS	NS	ND (0.0063)/ND (0.0063)	NS
5/1/2015	NS	NS	NS	ND (0.0064)/ND (0.0064)	NS
5/8/2015	NS	NS	NS	ND (0.0064)/ND (0.0064)	NS
5/15/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
5/21/2015	NS	NS	NS	ND (0.0074)/ND (0.0074)	NS
5/28/2015	NS	NS	NS	ND (0.0065)/ND (0.0065)	NS
No. of Detects	**0**	**0**	**0**	**0**	**0**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**NA**	**NA**	**NA**	**NA**	**NA**
Median	**NA**	**NA**	**NA**	**NA**	**NA**
Maximum	**NA**	**NA**	**NA**	**NA**	**NA**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

NA	not applicable
ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-5
Ethylbenzene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
12/27/2014	ND (0.0023)	ND (0.0023)	ND (0.0023)	ND (0.0023)/ND (0.0023)	ND (0.0023)
1/5/2015	ND (0.0022)	ND (0.0022)	ND (0.0022)	ND (0.0022)/ND (0.0022)	ND (0.0022)
1/19/2015	ND (0.0014)	ND (0.0014)	ND (0.0014)	ND (0.0014)/ND (0.0014)	ND (0.0014)
1/28/2015	0.32	0.31	0.29	0.310 /0.280	0.37
2/4/2015	ND (3.7)	ND (3.7)	ND (3.7)	ND (3.7)/ND (3.7)	ND (3.7)
2/13/2015	0.190 /0.210	0.19	0.2	0.18	0.26
2/20/2015	U	U	U	U/U	U
2/27/2015	U	U	U	U/U	U
3/6/2015	0.19	0.14	0.15	0.160 /0.130	0.14
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	U/U	NS
4/10/2015	NS	NS	NS	ND (0.0028)/ND (0.0028)	NS
4/17/2015	NS	NS	NS	ND (0.0028)/ND (0.0028)	NS
4/24/2015	NS	NS	NS	ND (0.0028)/ND (0.0028)	NS
5/1/2015	NS	NS	NS	ND (0.0029)/ND (0.0029)	NS
5/8/2015	NS	NS	NS	ND (0.0073)/ND (0.0073)	NS
5/15/2015	NS	NS	NS	0.250 /0.250	NS
5/21/2015	NS	NS	NS	ND (0.0084)/ND (0.0084)	NS
5/28/2015	NS	NS	NS	ND (0.0074)/ND (0.0074)	NS
No. of Detects	**4**	**3**	**3**	**7**	**3**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.19**	**0.14**	**0.15**	**0.13**	**0.14**
Median	**0.2**	**0.19**	**0.2**	**0.25**	**0.26**
Maximum	**0.32**	**0.31**	**0.29**	**0.31**	**0.37**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-6
Isopropylbenzene (Cumene)

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0029)	ND (0.0029)	ND (0.0029)	ND (0.0029)/ND (0.0029)	ND (0.0029)
12/27/2014	ND (0.0027)	ND (0.0027)	ND (0.0027)	ND (0.0027)/ND (0.0027)	ND (0.0027)
1/5/2015	ND (0.0026)	ND (0.0026)	ND (0.0026)	ND (0.0026)/ND (0.0026)	ND (0.0026)
1/19/2015	ND (0.0017)	ND (0.0017)	ND (0.0017)	ND (0.0017)/ND (0.0017)	ND (0.0017)
1/28/2015	0.028	0.025	0.023	0.025 /0.024	0.027
2/4/2015	ND (9.1)	ND (9.1)	ND (9.1)	ND (9.1)/ND (9.1)	ND (9.1)
2/13/2015	0.017 /ND (0.018)	0.016	0.017	0.016	0.018
2/20/2015	U	ND (0.019)	U	U/U	ND (0.019)
2/27/2015	U	U	U	U/U	U
3/6/2015	ND (0.08)	ND (0.08)	ND (0.08)	ND (0.08)/ND (0.08)	ND (0.08)
3/13/2015	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)/ND (1.0)	ND (1.0)
3/20/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
3/27/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
4/3/2015	NS	NS	NS	ND (0.019)/ND (0.019)	NS
4/10/2015	NS	NS	NS	ND (0.0033)/ND (0.0033)	NS
4/17/2015	NS	NS	NS	ND (0.0033)/ND (0.0033)	NS
4/24/2015	NS	NS	NS	ND (0.0033)/ND (0.0033)	NS
5/1/2015	NS	NS	NS	ND (0.0034)/ND (0.0034)	NS
5/8/2015	NS	NS	NS	ND (0.0085)/ND (0.0085)	NS
5/15/2015	NS	NS	NS	ND (0.08)/ND (0.08)	NS
5/21/2015	NS	NS	NS	ND (0.0098)/ND (0.0098)	NS
5/28/2015	NS	NS	NS	ND (0.0086)/ND (0.0086)	NS
No. of Detects	**2**	**2**	**2**	**3**	**2**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.017**	**0.016**	**0.017**	**0.016**	**0.018**
Median	**0.0225**	**0.0205**	**0.02**	**0.024**	**0.0225**
Maximum	**0.028**	**0.025**	**0.023**	**0.025**	**0.027**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-7
m&p-Xylene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0048)	ND (0.0048)	ND (0.0048)	ND (0.0048)/ND (0.0048)	ND (0.0048)
12/27/2014	ND (0.0045)	ND (0.0045)	ND (0.0045)	ND (0.0045)/ND (0.0045)	ND (0.0045)
1/5/2015	ND (0.0043)	ND (0.0043)	ND (0.0043)	ND (0.0043)/ND (0.0043)	ND (0.0043)
1/19/2015	ND (0.0028)	ND (0.0028)	ND (0.0028)	ND (0.0028)/ND (0.0028)	ND (0.0028)
1/28/2015	0.97	0.96	0.88	0.910 /0.840	1.1
2/4/2015	ND (7.1)	ND (7.1)	ND (7.1)	ND (7.1)/ND (7.1)	ND (7.1)
2/13/2015	0.510 /0.490	0.49	0.52	0.46	0.65
2/20/2015	U	U	U	ND (0.046)/U	U
2/27/2015	U	U	U	U/U	U
3/6/2015	0.44	0.35	0.38	0.380 /0.320	0.36
3/13/2015	ND (0.82)	ND (0.83)	ND (0.83)	0.870 /0.940	0.87
3/20/2015	NS	NS	NS	ND (0.8)/ND (0.8)	NS
3/27/2015	NS	NS	NS	ND (0.8)/ND (0.8)	NS
4/3/2015	NS	NS	NS	U/U	NS
4/10/2015	NS	NS	NS	ND (0.0056)/ND (0.0056)	NS
4/17/2015	NS	NS	NS	ND (0.0056)/ND (0.0056)	NS
4/24/2015	NS	NS	NS	ND (0.0055)/ND (0.0055)	NS
5/1/2015	NS	NS	NS	ND (0.0056)/ND (0.0056)	NS
5/8/2015	NS	NS	NS	ND (0.007)/ND (0.007)	NS
5/15/2015	NS	NS	NS	0.700 /0.700	NS
5/21/2015	NS	NS	NS	ND (0.0081)/ND (0.0081)	NS
5/28/2015	NS	NS	NS	ND (0.0071)/ND (0.0071)	NS
No. of Detects	**4**	**3**	**3**	**9**	**4**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.44**	**0.35**	**0.38**	**0.32**	**0.36**
Median	**0.5**	**0.49**	**0.52**	**0.7**	**0.76**
Maximum	**0.97**	**0.96**	**0.88**	**0.94**	**1.1**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

Table B-8
Methyl-tert-butyl ether

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0026)	ND (0.0026)	ND (0.0026)	ND (0.0026)/ND (0.0026)	ND (0.0026)
12/27/2014	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
1/5/2015	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
1/19/2015	ND (0.0015)	ND (0.0015)	ND (0.0015)	ND (0.0015)/ND (0.0015)	ND (0.0015)
1/28/2015	0.022	0.023	0.024	0.023 /0.027	0.029
2/4/2015	ND (3.2)	ND (3.2)	ND (3.2)	ND (3.2)/ND (3.2)	ND (3.2)
2/13/2015	ND (0.0052)/ND (0.0061)	ND (0.0052)	ND (0.0052)	ND (0.0052)	ND (0.0052)
2/20/2015	ND (0.0066)	U	U	U/U	ND (0.0066)
2/27/2015	0.041	0.038	0.039	0.041 /0.035	0.039
3/6/2015	U	U	U	U/U	U
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	ND (0.0066)/ND (0.0066)	NS
4/10/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
4/17/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
4/24/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
5/1/2015	NS	NS	NS	ND (0.0031)/ND (0.0031)	NS
5/8/2015	NS	NS	NS	ND (0.0076)/ND (0.0076)	NS
5/15/2015	NS	NS	NS	ND (0.07)/ND (0.07)	NS
5/21/2015	NS	NS	NS	ND (0.0088)/ND (0.0088)	NS
5/28/2015	NS	NS	NS	ND (0.0077)/ND (0.0077)	NS
No. of Detects	**2**	**2**	**2**	**4**	**2**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.022**	**0.023**	**0.024**	**0.023**	**0.029**
Median	**0.0315**	**0.0305**	**0.0315**	**0.031**	**0.034**
Maximum	**0.041**	**0.038**	**0.039**	**0.041**	**0.039**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-9
o-Xylene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0026)	ND (0.0026)	ND (0.0026)	ND (0.0026)/ND (0.0026)	ND (0.0026)
12/27/2014	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
1/5/2015	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
1/19/2015	ND (0.0015)	ND (0.0015)	ND (0.0015)	ND (0.0015)/ND (0.0015)	ND (0.0015)
1/28/2015	0.34	0.33	0.3	0.310 /0.290	0.39
2/4/2015	ND (3.9)	ND (3.9)	ND (3.9)	ND (3.9)/ND (3.9)	ND (3.9)
2/13/2015	0.180 /0.180	0.18	0.19	0.17	0.24
2/20/2015	U	U	U	U/U	U
2/27/2015	U	U	U	U/U	U
3/6/2015	0.16	0.14	0.14	0.140 /0.120	0.13
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	U/U	NS
4/10/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
4/17/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
4/24/2015	NS	NS	NS	ND (0.003)/ND (0.003)	NS
5/1/2015	NS	NS	NS	ND (0.0031)/ND (0.0031)	NS
5/8/2015	NS	NS	NS	ND (0.0076)/ND (0.0076)	NS
5/15/2015	NS	NS	NS	0.250 /0.250	NS
5/21/2015	NS	NS	NS	ND (0.0088)/ND (0.0088)	NS
5/28/2015	NS	NS	NS	ND (0.0077)/ND (0.0077)	NS
No. of Detects	**4**	**3**	**3**	**7**	**3**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.16**	**0.14**	**0.14**	**0.12**	**0.13**
Median	**0.18**	**0.18**	**0.19**	**0.25**	**0.24**
Maximum	**0.34**	**0.33**	**0.3**	**0.31**	**0.39**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

Table B-10
Tetrachloroethene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0029)	ND (0.0029)	ND (0.0029)	ND (0.0029)/ND (0.0029)	ND (0.0029)
12/27/2014	ND (0.0027)	ND (0.0027)	ND (0.0027)	ND (0.0027)/ND (0.0027)	ND (0.0027)
1/5/2015	ND (0.0026)	ND (0.0026)	ND (0.0026)	ND (0.0026)/ND (0.0026)	ND (0.0026)
1/19/2015	ND (0.0017)	ND (0.0017)	ND (0.0017)	ND (0.0017)/ND (0.0017)	ND (0.0017)
1/28/2015	0.26	0.46	0.16	0.180 /0.180	0.23
2/4/2015	ND (9.4)	ND (9.4)	ND (9.4)	ND (9.4)/ND (9.4)	ND (9.4)
2/13/2015	0.120 /0.130	0.12	0.12	0.11	0.13
2/20/2015	U	U	U	U/U	U
2/27/2015	0.12	0.085	0.087	0.085 /0.084	ND (0.082)
3/6/2015	0.16	0.096	0.095	0.110 /0.100	0.085
3/13/2015	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)/ND (1.0)	ND (1.0)
3/20/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
3/27/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
4/3/2015	NS	NS	NS	0.150 /0.300	NS
4/10/2015	NS	NS	NS	ND (0.0083)/ND (0.0083)	NS
4/17/2015	NS	NS	NS	ND (0.0083)/ND (0.0083)	NS
4/24/2015	NS	NS	NS	ND (0.0082)/ND (0.0082)	NS
5/1/2015	NS	NS	NS	ND (0.0084)/ND (0.0084)	NS
5/8/2015	NS	NS	NS	ND (0.0084)/ND (0.0084)	NS
5/15/2015	NS	NS	NS	U/U	NS
5/21/2015	NS	NS	NS	ND (0.0097)/ND (0.0097)	NS
5/28/2015	NS	NS	NS	ND (0.0085)/ND (0.0085)	NS
No. of Detects	**5**	**4**	**4**	**9**	**3**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.12**	**0.085**	**0.087**	**0.084**	**0.085**
Median	**0.13**	**0.108**	**0.1075**	**0.11**	**0.13**
Maximum	**0.26**	**0.46**	**0.16**	**0.3**	**0.23**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( ) not detected (method detection limit)

NS not sampled

Table B-11
Toluene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0023)	ND (0.0023)	ND (0.0023)	ND (0.0023)/ND (0.0023)	ND (0.0023)
12/27/2014	ND (0.0021)	ND (0.0021)	ND (0.0021)	ND (0.0021)/ND (0.0021)	ND (0.0021)
1/5/2015	ND (0.0021)	ND (0.0021)	ND (0.0021)	ND (0.0021)/ND (0.0021)	ND (0.0021)
1/19/2015	ND (0.0013)	ND (0.0013)	ND (0.0013)	ND (0.0013)/ND (0.0013)	ND (0.0013)
2/20/2015	NR	NR	U	U	NR
3/20/2015	NS	NS	NS	1.100 /1.100	NS
4/10/2015	NS	NS	NS	ND (0.0026)/ND (0.0026)	NS
4/17/2015	NS	NS	NS	ND (0.0026)/ND (0.0026)	NS
4/24/2015	NS	NS	NS	ND (0.0026)/ND (0.0026)	NS
5/1/2015	NS	NS	NS	ND (0.0027)/ND (0.0027)	NS
5/8/2015	NS	NS	NS	ND (0.0067)/ND (0.0067)	NS
5/15/2015	NS	NS	NS	1.200 /1.200	NS
5/21/2015	NS	NS	NS	ND (0.0078)/ND (0.0078)	NS
5/28/2015	NS	NS	NS	ND (0.0068)/ND (0.0068)	NS
No. of Detects	**0**	**0**	**0**	**4**	**0**
No. of Samples	**4**	**4**	**5**	**28**	**4**
Minimum	**NA**	**NA**	**NA**	**1.1**	**NA**
Median	**NA**	**NA**	**NA**	**1.15**	**NA**
Maximum	**NA**	**NA**	**NA**	**1.2**	**NA**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

NA	not applicable
ND ( )	not detected (method detection limit)
NR	not reported by laboratory
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-12
trans-1,2-Dichloroethene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0022)	ND (0.0022)	ND (0.0022)	ND (0.0022)/ND (0.0022)	ND (0.0022)
12/27/2014	ND (0.0021)	ND (0.0021)	ND (0.0021)	ND (0.0021)/ND (0.0021)	ND (0.0021)
1/5/2015	ND (0.002)	ND (0.002)	ND (0.002)	ND (0.002)/ND (0.002)	ND (0.002)
1/19/2015	ND (0.0013)	ND (0.0013)	ND (0.0013)	ND (0.0013)/ND (0.0013)	ND (0.0013)
1/28/2015	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)/ND (0.0059)	ND (0.0059)
2/4/2015	ND (3.7)	ND (3.7)	ND (3.7)	ND (3.7)/ND (3.7)	ND (3.7)
2/13/2015	ND (0.0059)/ND (0.0071)	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)
2/20/2015	ND (0.0076)	ND (0.0076)	U	ND (0.0076)/U	ND (0.0076)
2/27/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/6/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	ND (0.0076)/ND (0.0076)	NS
4/10/2015	NS	NS	NS	ND (0.0025)/ND (0.0025)	NS
4/17/2015	NS	NS	NS	ND (0.0025)/ND (0.0025)	NS
4/24/2015	NS	NS	NS	ND (0.0025)/ND (0.0025)	NS
5/1/2015	NS	NS	NS	ND (0.0026)/ND (0.0026)	NS
5/8/2015	NS	NS	NS	ND (0.0064)/ND (0.0064)	NS
5/15/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
5/21/2015	NS	NS	NS	ND (0.0074)/ND (0.0074)	NS
5/28/2015	NS	NS	NS	ND (0.0065)/ND (0.0065)	NS
No. of Detects	**0**	**0**	**0**	**0**	**0**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**NA**	**NA**	**NA**	**NA**	**NA**
Median	**NA**	**NA**	**NA**	**NA**	**NA**
Maximum	**NA**	**NA**	**NA**	**NA**	**NA**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

NA	not applicable
ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-13
Trichloroethene

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.0024)	ND (0.0024)	ND (0.0024)	ND (0.0024)/ND (0.0024)	ND (0.0024)
12/27/2014	ND (0.0023)	ND (0.0023)	ND (0.0023)	ND (0.0023)/ND (0.0023)	ND (0.0023)
1/5/2015	ND (0.0022)	ND (0.0022)	ND (0.0022)	ND (0.0022)/ND (0.0022)	ND (0.0022)
1/19/2015	ND (0.0014)	ND (0.0014)	ND (0.0014)	ND (0.0014)/ND (0.0014)	ND (0.0014)
1/28/2015	0.1	0.51	0.11	0.150 /0.150	0.087
2/4/2015	ND (8.8)	ND (8.8)	ND (8.8)	ND (8.8)/ND (8.8)	ND (8.8)
2/13/2015	0.042 /0.041	0.33	0.044	0.048	0.063
2/20/2015	0.044	0.41	U	0.170 /U	0.079
2/27/2015	ND (0.077)	0.24	ND (0.077)	ND (0.077)/ND (0.077)	0.12
3/6/2015	ND (0.077)	0.11	ND (0.077)	ND (0.077)/ND (0.077)	ND (0.077)
3/13/2015	ND (1.0)	ND (1.0)	ND (1.0)	ND (1.0)/ND (1.0)	ND (1.0)
3/20/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
3/27/2015	NS	NS	NS	ND (1.0)/ND (1.0)	NS
4/3/2015	NS	NS	NS	0.043 /0.043	NS
4/10/2015	NS	NS	NS	ND (0.0071)/ND (0.0071)	NS
4/17/2015	NS	NS	NS	ND (0.0071)/ND (0.0071)	NS
4/24/2015	NS	NS	NS	ND (0.007)/ND (0.007)	NS
5/1/2015	NS	NS	NS	ND (0.0071)/ND (0.0071)	NS
5/8/2015	NS	NS	NS	ND (0.0071)/ND (0.0071)	NS
5/15/2015	NS	NS	NS	0.079 /ND (0.077)	NS
5/21/2015	NS	NS	NS	ND (0.0082)/ND (0.0082)	NS
5/28/2015	NS	NS	NS	ND (0.0072)/ND (0.0072)	NS
No. of Detects	**4**	**5**	**2**	**7**	**4**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**0.041**	**0.11**	**0.044**	**0.043**	**0.063**
Median	**0.043**	**0.33**	**0.077**	**0.079**	**0.083**
Maximum	**0.1**	**0.51**	**0.11**	**0.17**	**0.12**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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Table B-14
Vinyl chloride

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	ND (0.014)	ND (0.014)	ND (0.014)	ND (0.014)/ND (0.014)	ND (0.014)
12/27/2014	ND (0.013)	ND (0.013)	ND (0.013)	ND (0.013)/ND (0.013)	ND (0.013)
1/5/2015	ND (0.013)	ND (0.013)	ND (0.013)	ND (0.013)/ND (0.013)	ND (0.013)
1/19/2015	ND (0.0083)	ND (0.0083)	ND (0.0083)	ND (0.0083)/ND (0.0083)	ND (0.0083)
1/28/2015	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)/ND (0.0059)	ND (0.0059)
2/4/2015	ND (3.7)	ND (3.7)	ND (3.7)	ND (3.7)/ND (3.7)	ND (3.7)
2/13/2015	ND (0.0059)/ND (0.0071)	ND (0.0059)	ND (0.0059)	ND (0.0059)	ND (0.0059)
2/20/2015	ND (0.0076)	ND (0.0076)	U	ND (0.0076)/U	ND (0.0076)
2/27/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/6/2015	ND (0.032)	ND (0.032)	ND (0.032)	ND (0.032)/ND (0.032)	ND (0.032)
3/13/2015	ND (0.41)	ND (0.41)	ND (0.41)	ND (0.41)/ND (0.41)	ND (0.41)
3/20/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
3/27/2015	NS	NS	NS	ND (0.4)/ND (0.4)	NS
4/3/2015	NS	NS	NS	ND (0.0076)/ND (0.0076)	NS
4/10/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
4/17/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
4/24/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
5/1/2015	NS	NS	NS	U/U	NS
5/8/2015	NS	NS	NS	ND (0.016)/ND (0.016)	NS
5/15/2015	NS	NS	NS	ND (0.032)/ND (0.032)	NS
5/21/2015	NS	NS	NS	ND (0.018)/ND (0.018)	NS
5/28/2015	NS	NS	NS	ND (0.016)/ND (0.016)	NS
No. of Detects	**0**	**0**	**0**	**0**	**0**
No. of Samples	**12**	**11**	**11**	**44**	**11**
Minimum	**NA**	**NA**	**NA**	**NA**	**NA**
Median	**NA**	**NA**	**NA**	**NA**	**NA**
Maximum	**NA**	**NA**	**NA**	**NA**	**NA**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

NA	not applicable
ND ( )	not detected (method detection limit)
NS	not sampled

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Table B-15
Hydrogen Sulfide

Date Collected	Station 1	Station 2	Station 3	Station 4	Station 5
12/18/2014	0.570 J	0.560 J	0.540 J	0.570 J/0.510 J	0.640 J
12/27/2014	0.400 J	0.490 J	0.460 J	0.400 J/0.590 J	0.510 J
1/5/2015	0.530 J	0.370 J	0.550 J	0.600 J/0.620 J	0.550 J
1/19/2015	0.290 J	0.220 J	0.160 J	0.300 J/0.240 J	0.240 J
1/28/2015	0.450 J	0.390 J	0.380 J	0.590 J/0.410 J	0.250 J
2/4/2015	0.310 J	0.240 J	ND (0.21)	0.280 J/0.280 J	0.260 J
2/13/2015	ND (0.17)/ND (0.17)	ND (0.17)	ND (0.17)	ND (0.17)	ND (0.17)
2/20/2015	ND (0.25)	0.390 J	U	ND (0.023)/U	ND (0.25)
2/27/2015	ND (0.24)	ND (0.24)	ND (0.24)	ND (0.24)/ND (0.24)	ND (0.24)
3/6/2015	ND (0.23)	ND (0.23)	ND (0.23)	ND (0.23)/0.240 J	ND (0.23)
3/13/2015	0.240 J	0.480 J	ND (0.2)	0.430 J/0.380 J	0.310 J
4/3/2015	NS	NS	NS	ND (0.19)/ND (0.19)	NS
4/10/2015	NS	NS	NS	0.200 J/ND (0.18)	NS
4/17/2015	NS	NS	NS	ND (0.17)/ND (0.17)	NS
4/24/2015	NS	NS	NS	ND (0.18)/ND (0.18)	NS
5/1/2015	NS	NS	NS	ND (0.18)/ND (0.18)	NS
5/8/2015	NS	NS	NS	ND (0.16)/ND (0.16)	NS
5/15/2015	NS	NS	NS	ND (0.17)/0.210 J	NS
5/21/2015	NS	NS	NS	0.210 J/ND (0.2)	NS
5/28/2015	NS	NS	NS	ND (0.17)/ND (0.17)	NS
No. of Detects	**7**	**8**	**5**	**18**	**7**
No. of Samples	**12**	**11**	**11**	**39**	**11**
Minimum	**0.24**	**0.22**	**0.16**	**0.2**	**0.24**
Median	**0.4**	**0.39**	**0.46**	**0.39**	**0.31**
Maximum	**0.57**	**0.56**	**0.55**	**0.62**	**0.64**

Notes:

All concentrations in micrograms per cubic meter ($\mu g/m^3$)

J	laboratory flag indicating an estimated result less than reporting limit
ND ( )	not detected (method detection limit)
NS	not sampled
U	indicates a sample flagged by the data validator as not meeting data quality objectives; result is considered a non-detect

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APPENDIX C

TIME-SERIES PLOTS

WLLFOIA4312 - 015 - 0154856

Exhibit C-1
1,2,4-Trimethylbenzene

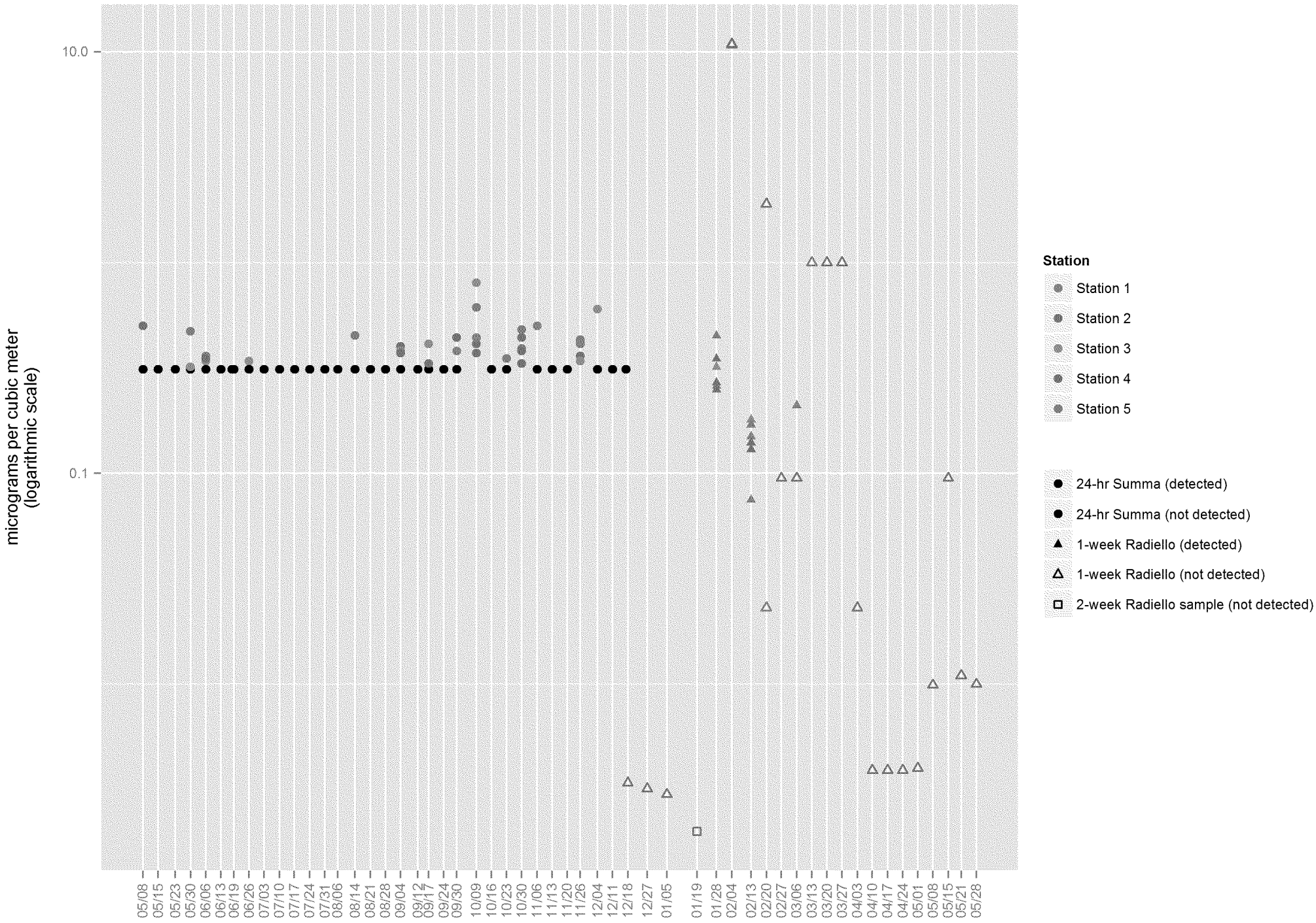


Exhibit C-2
1,3,5-Trimethylbenzene

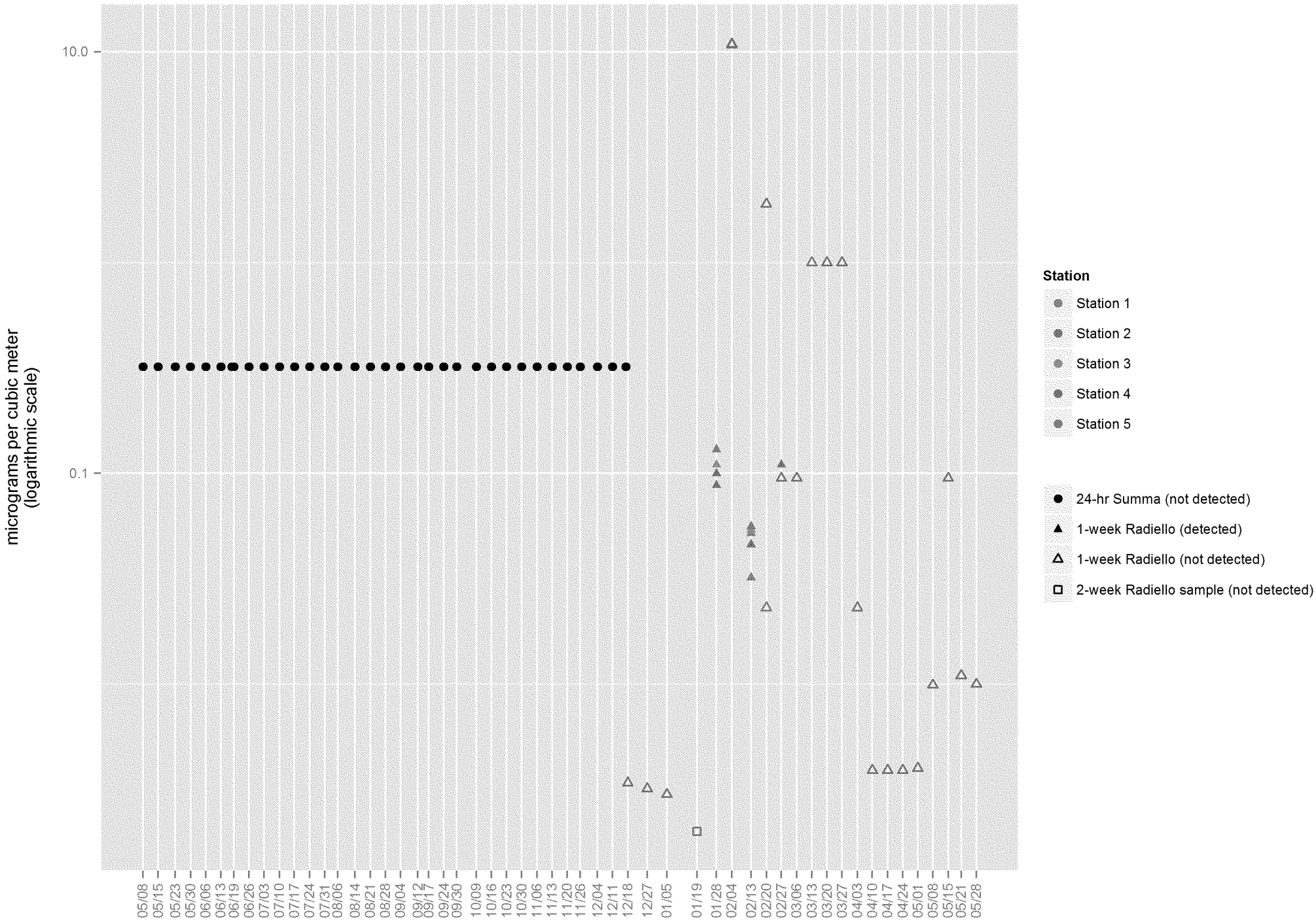


Exhibit C-3
Benzene

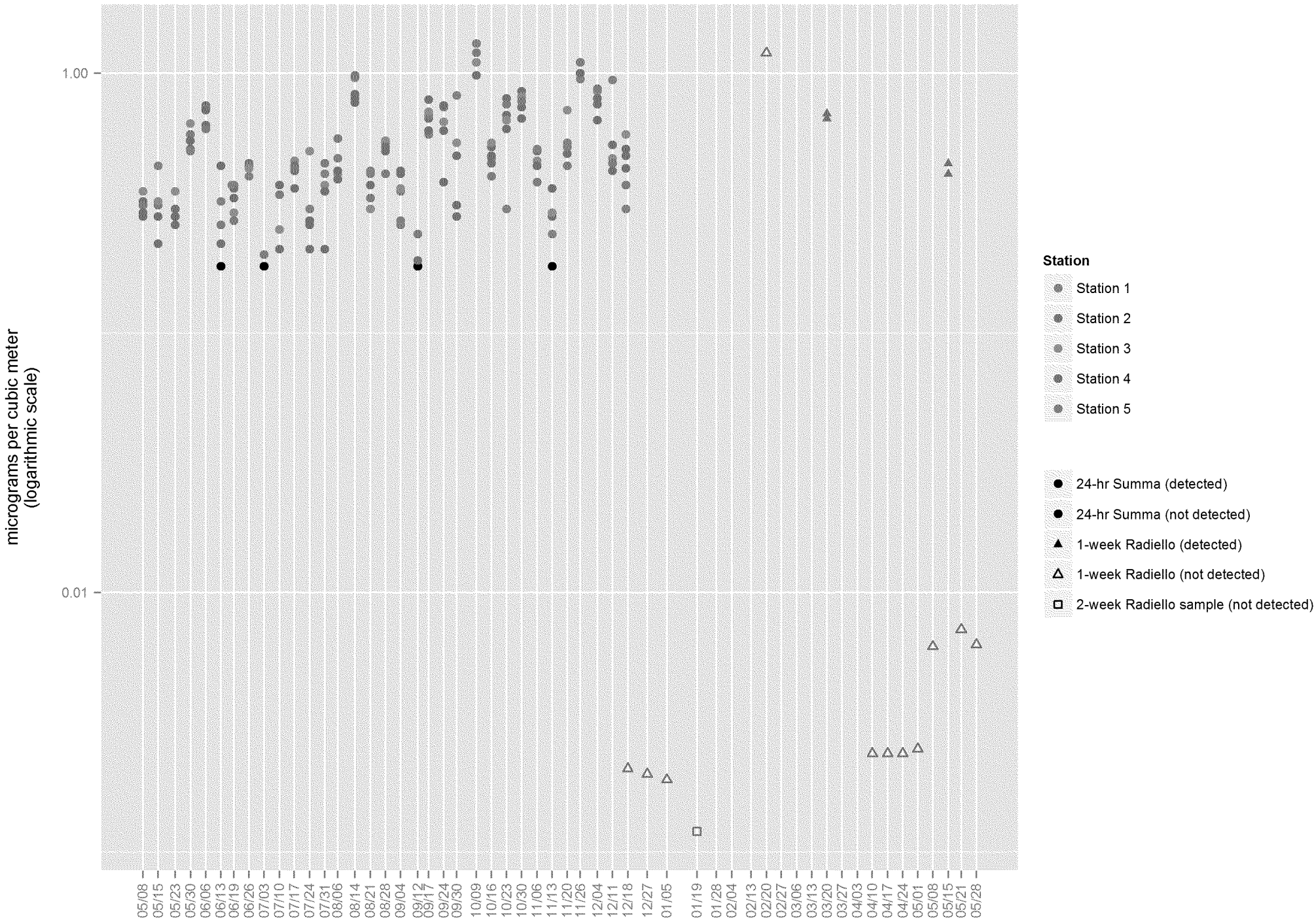


Exhibit C-4
cis-1,2-Dichloroethene

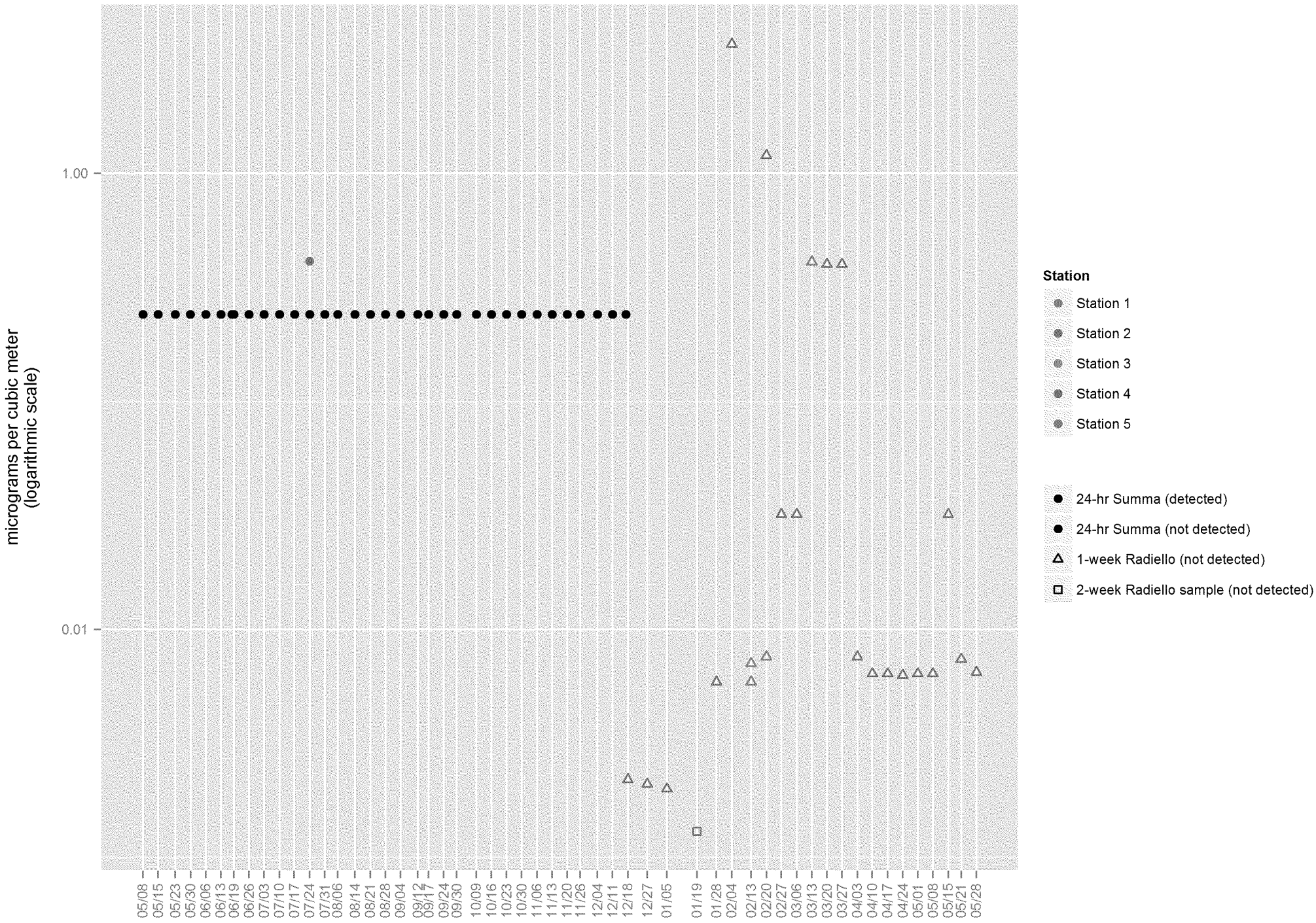


Exhibit C-5
Ethylbenzene

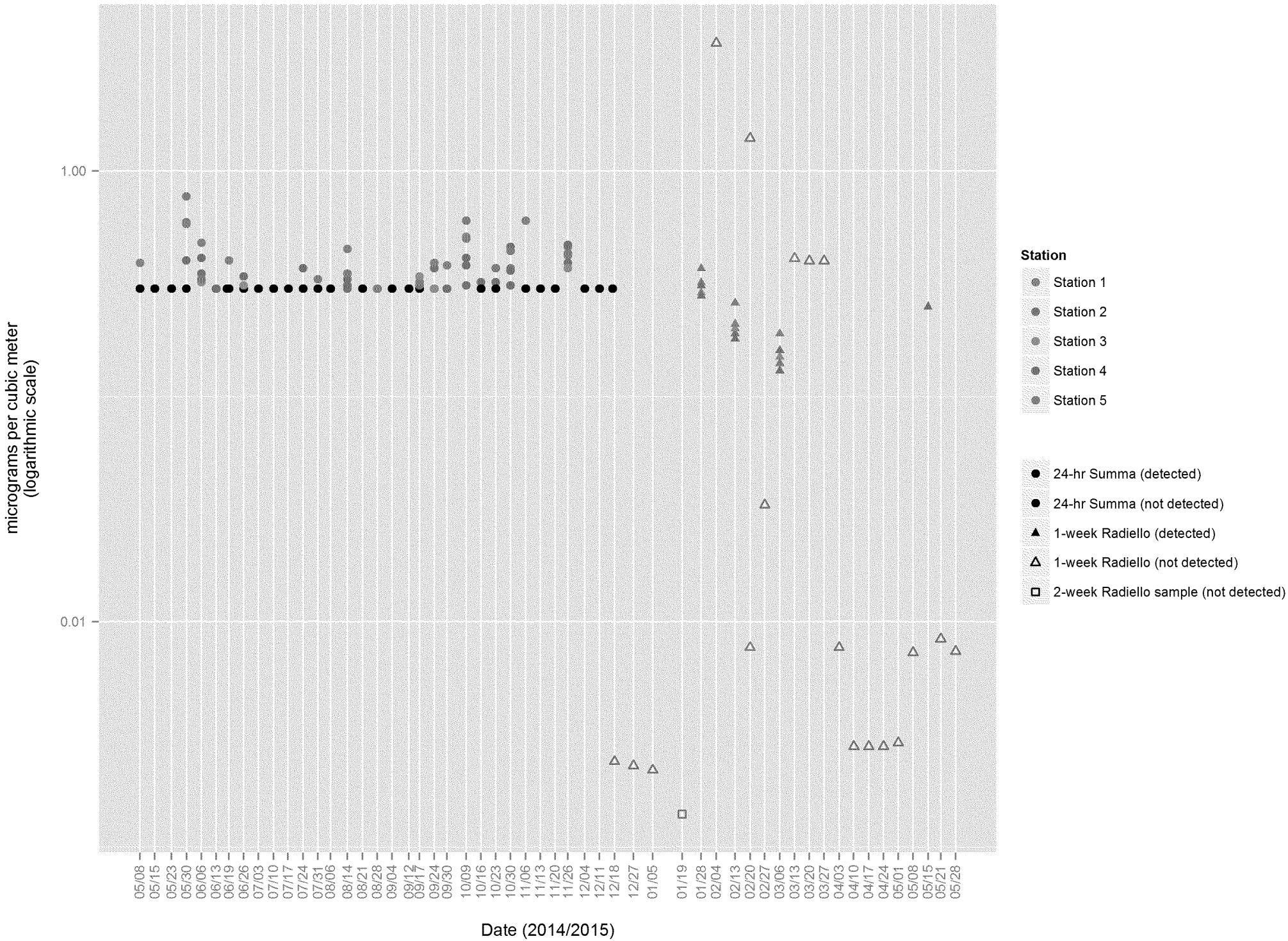


Exhibit C-6
Hydrogen Sulfide

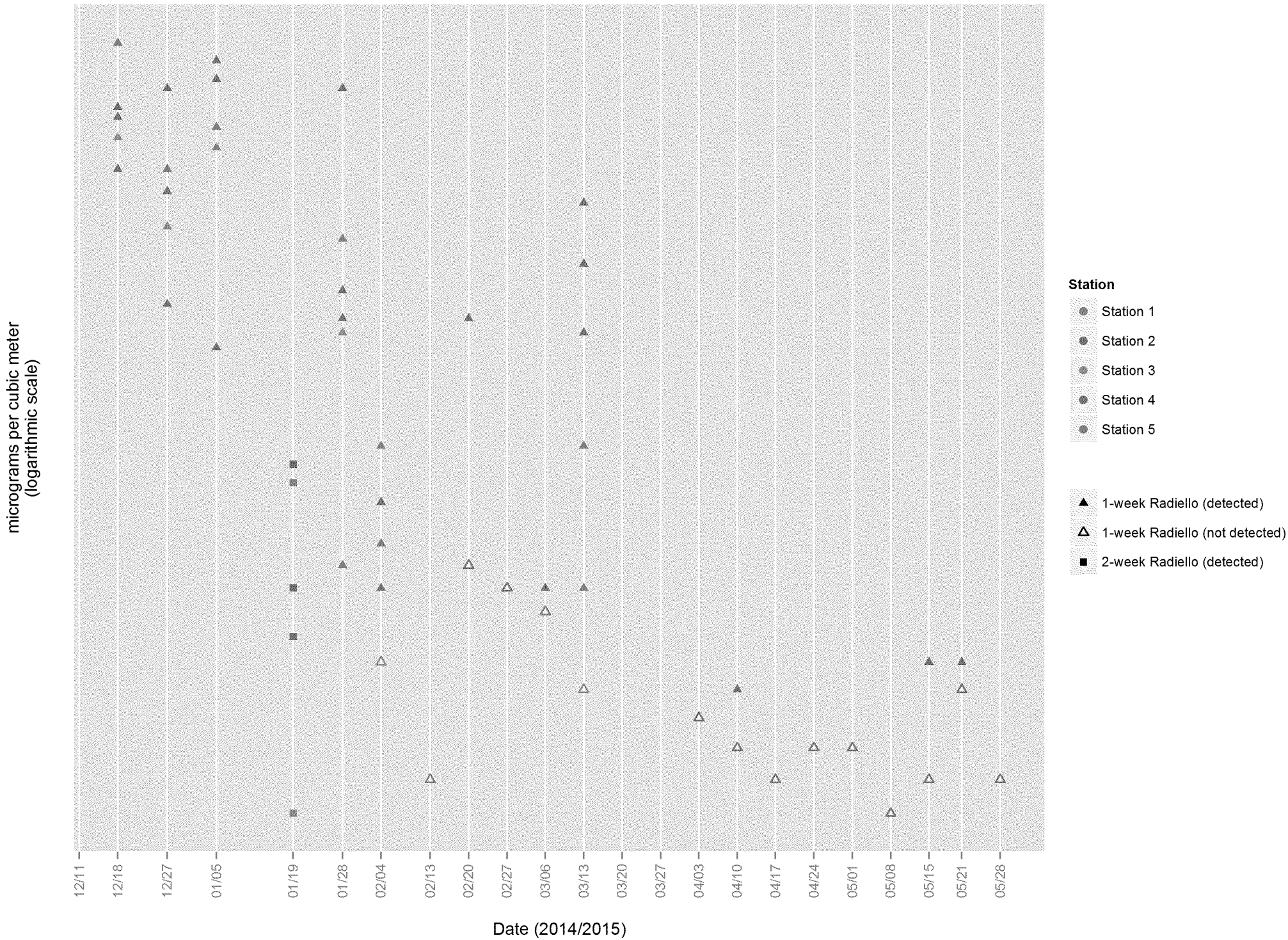


Exhibit C-7
Isopropylbenzene (Cumene)

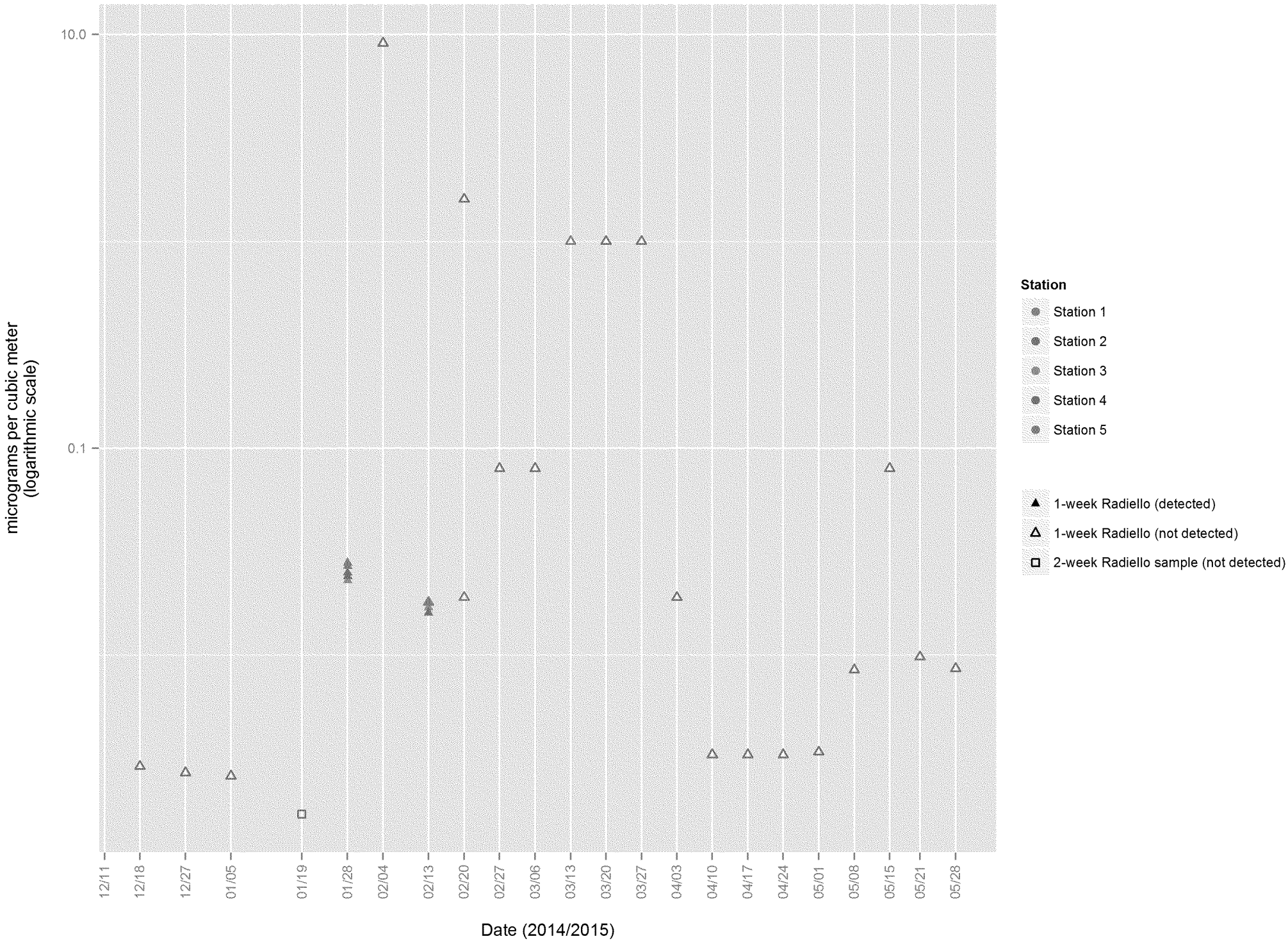


Exhibit C-8
m&p-Xylene

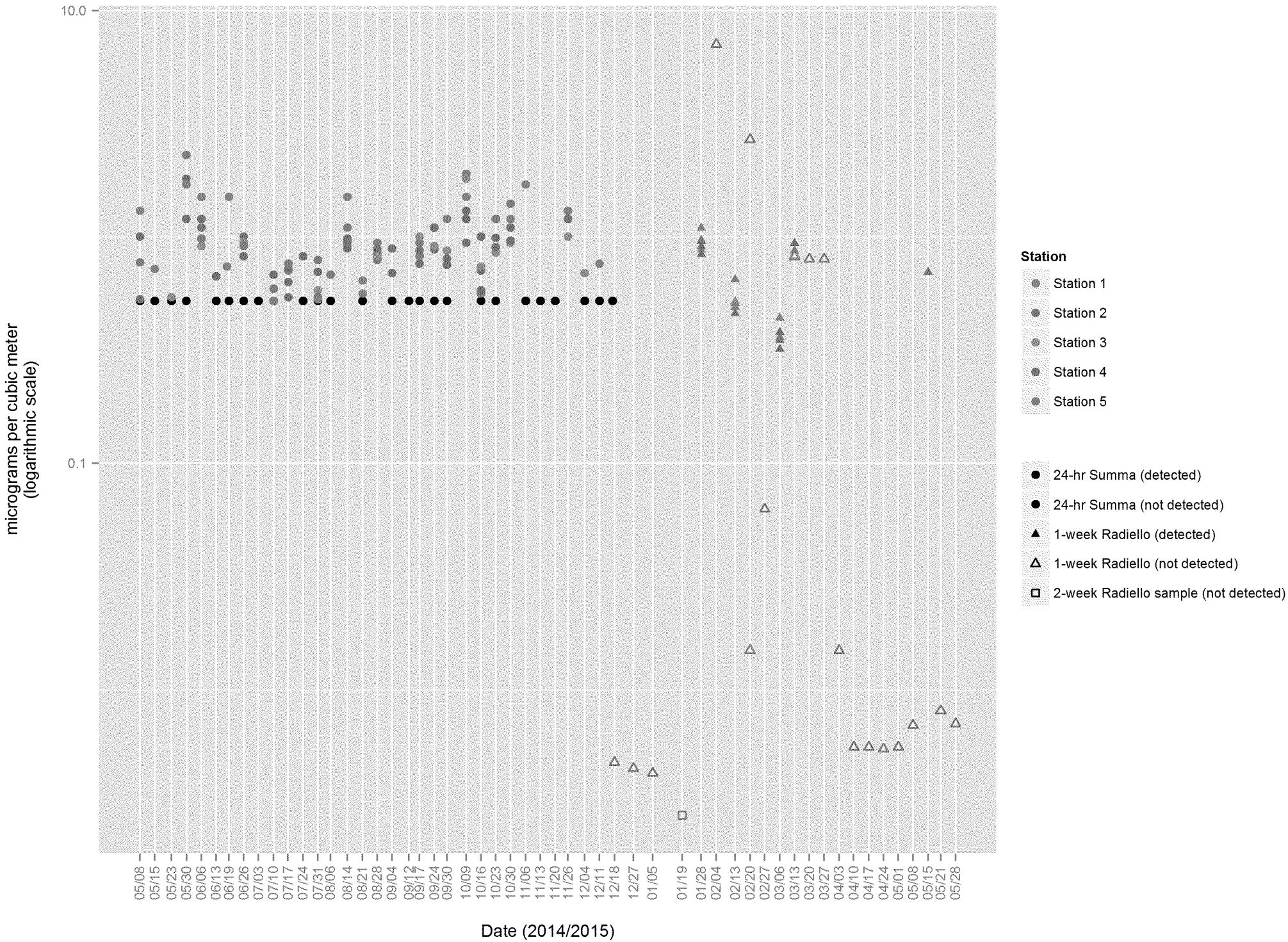


Exhibit C-9
Methyl-tert-butyl ether

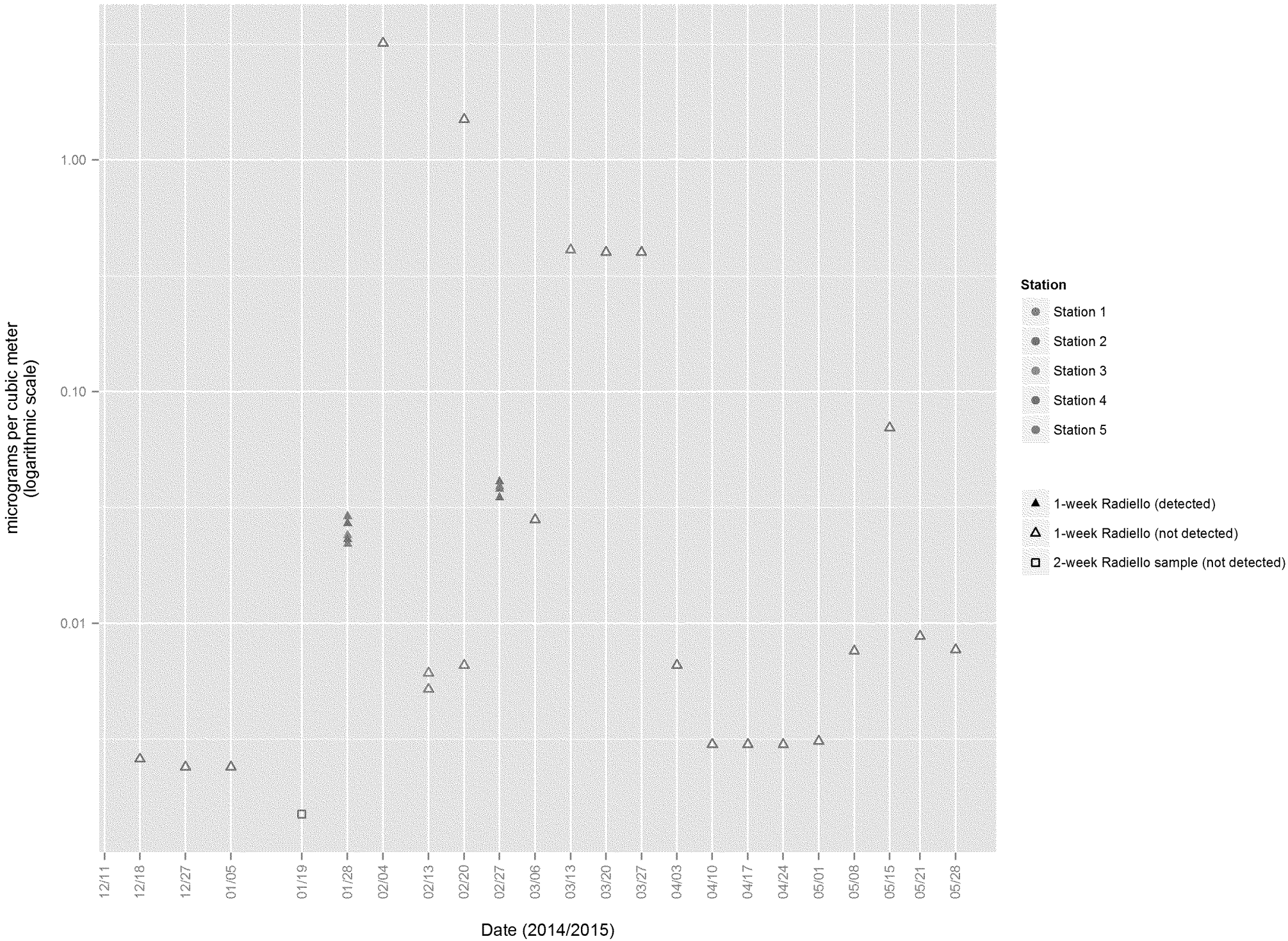


Exhibit C-10
o-Xylene

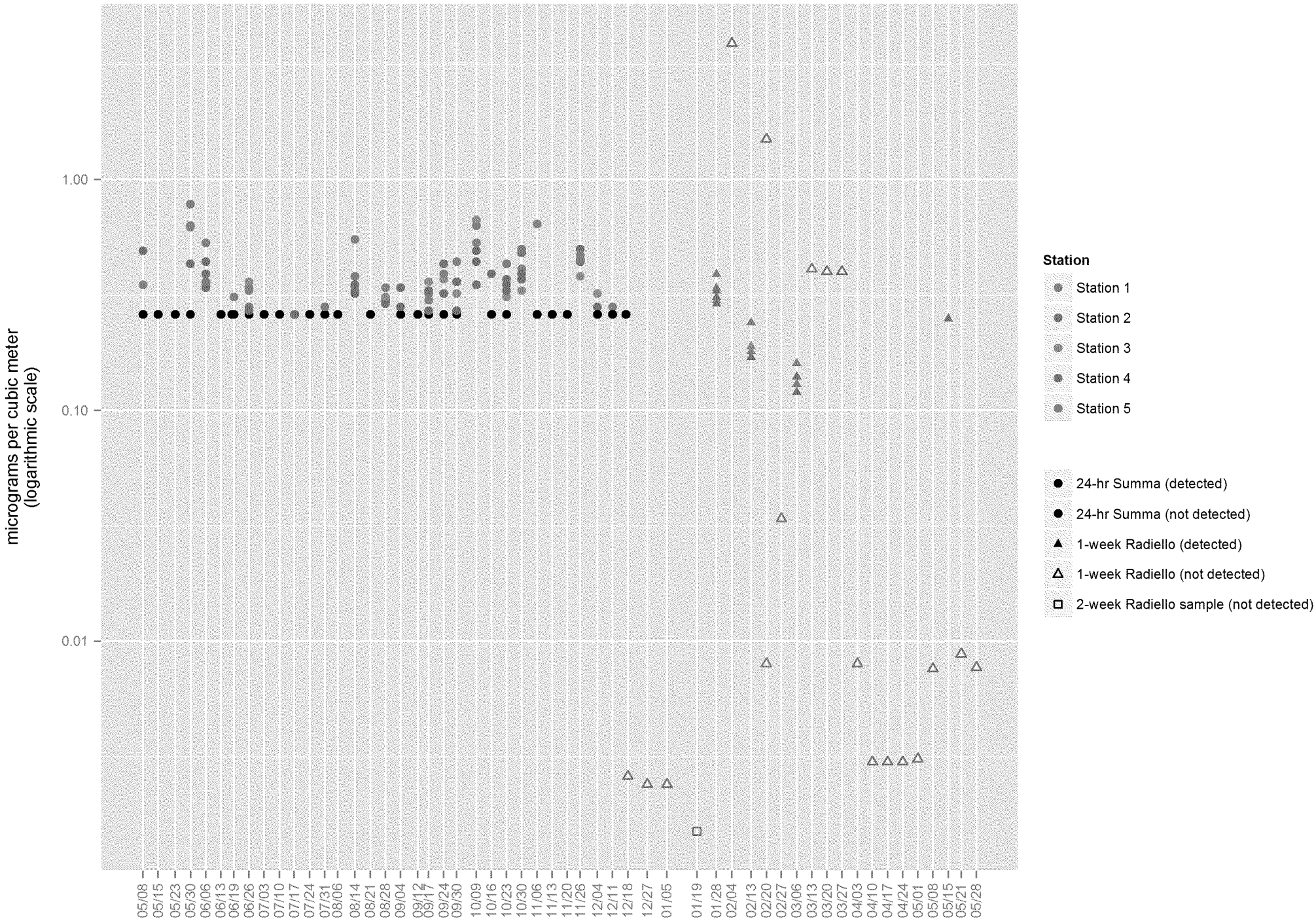


Exhibit C-11
Tetrachloroethene

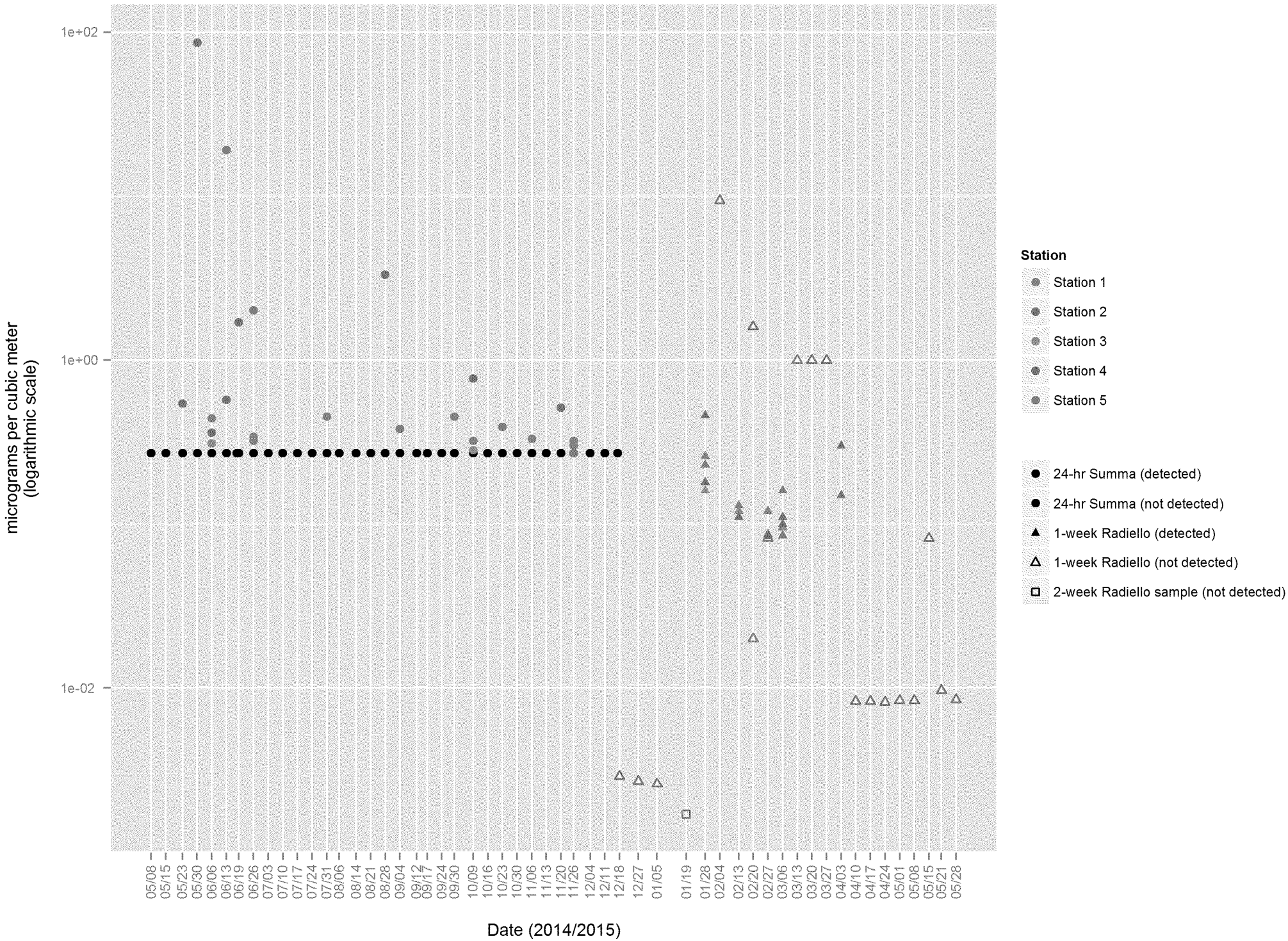


Exhibit C-12
Toluene

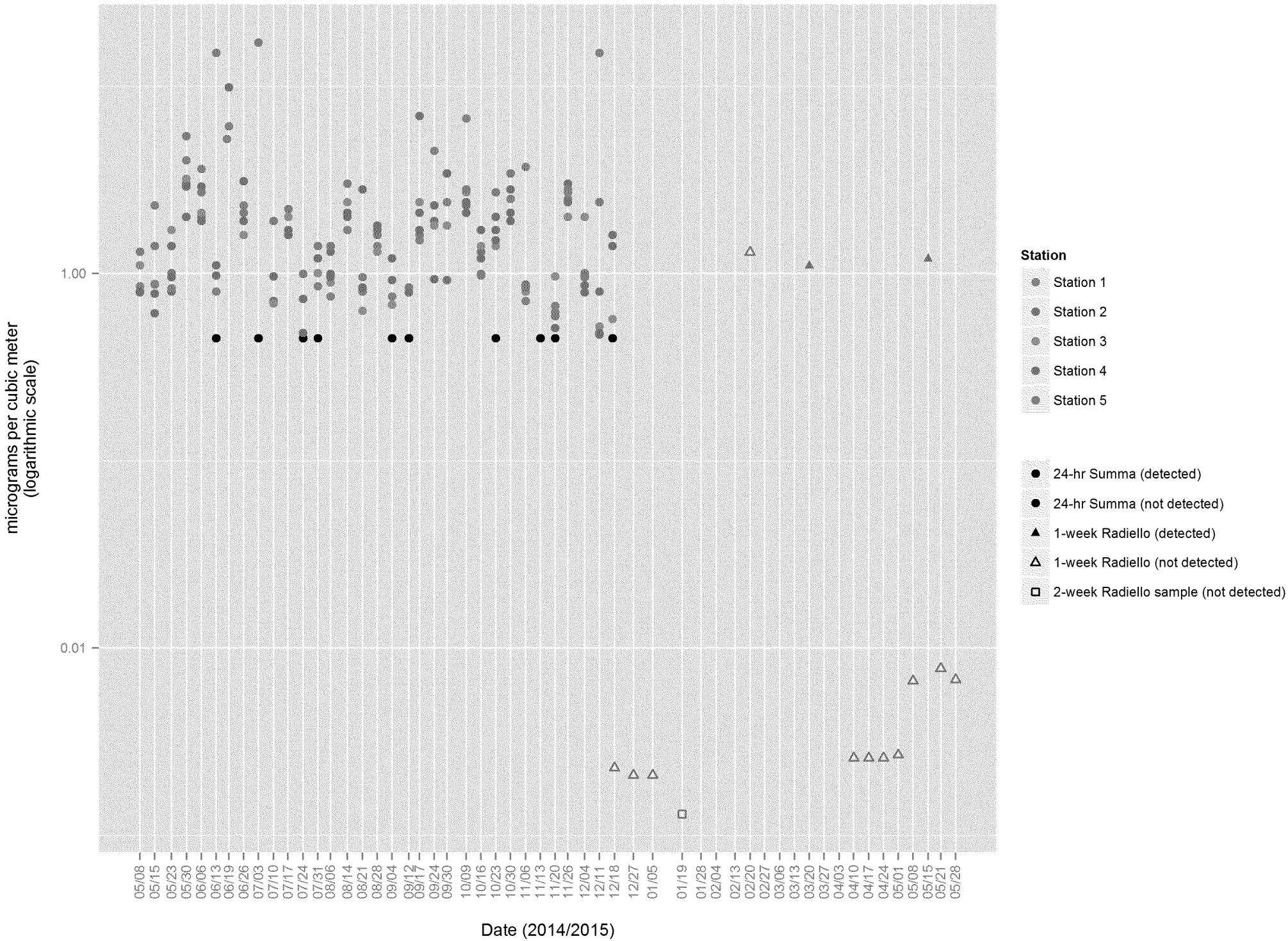


Exhibit C-13
trans-1,2-Dichloroethene

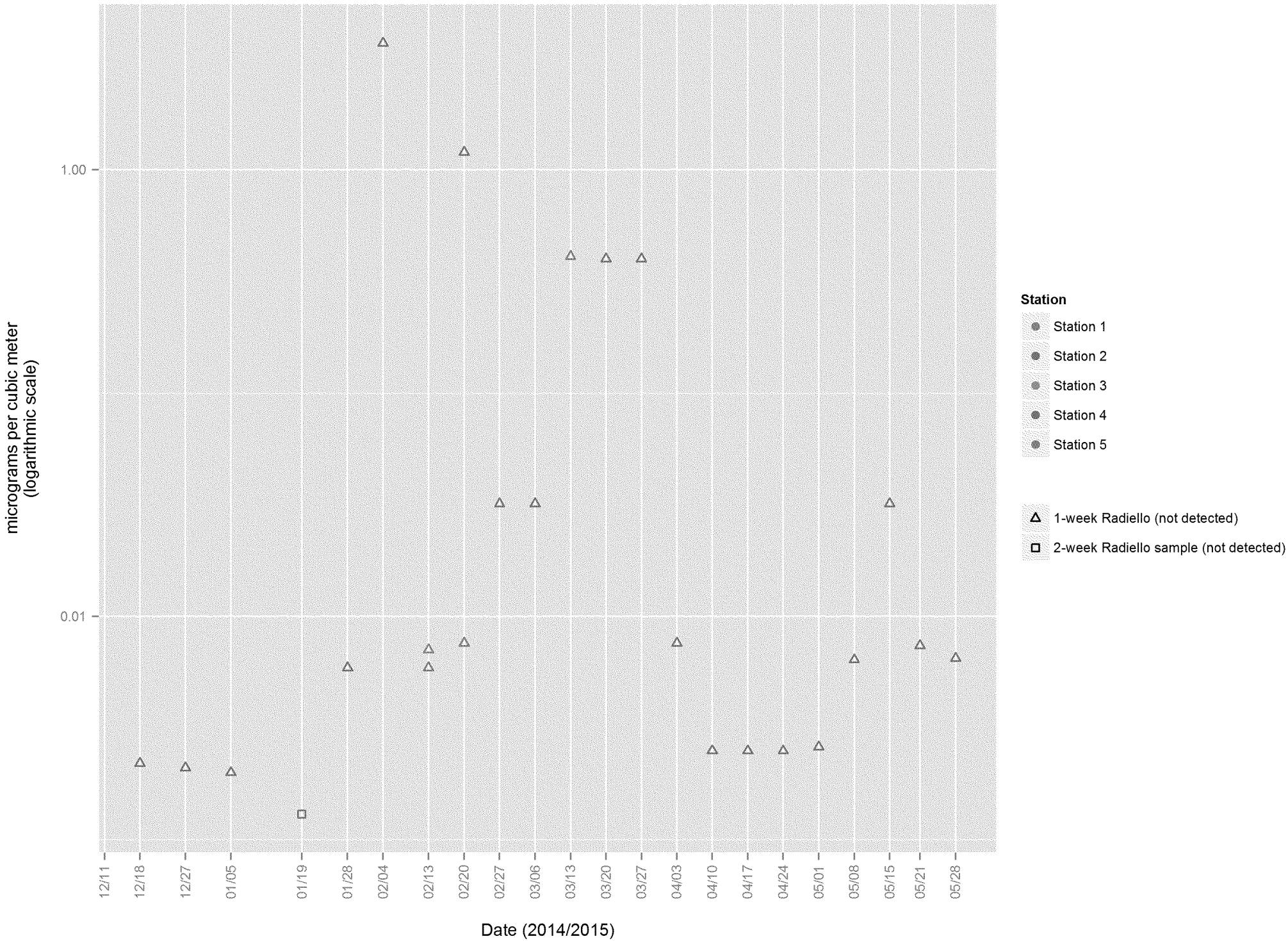


Exhibit C-14
Trichloroethene

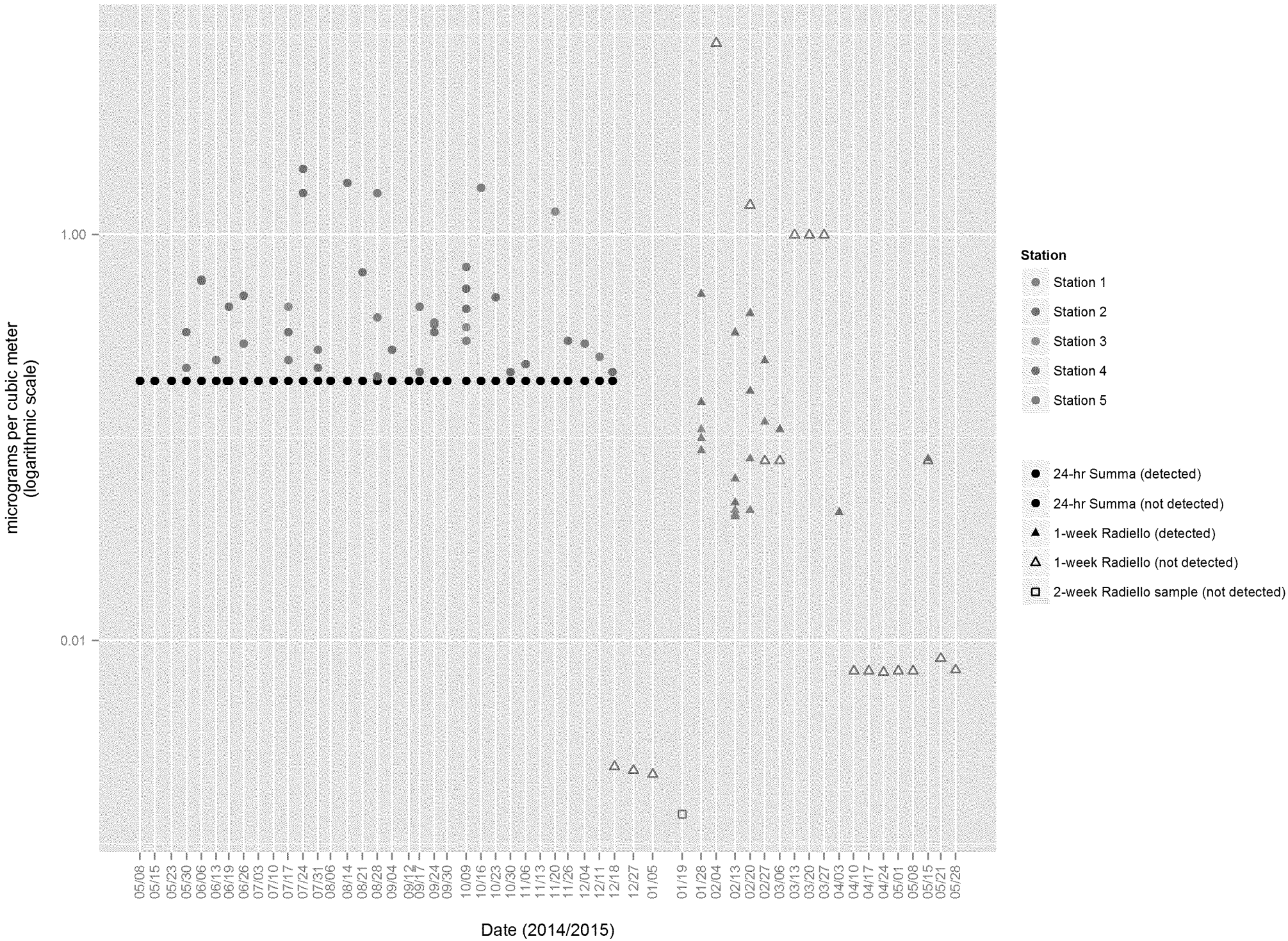
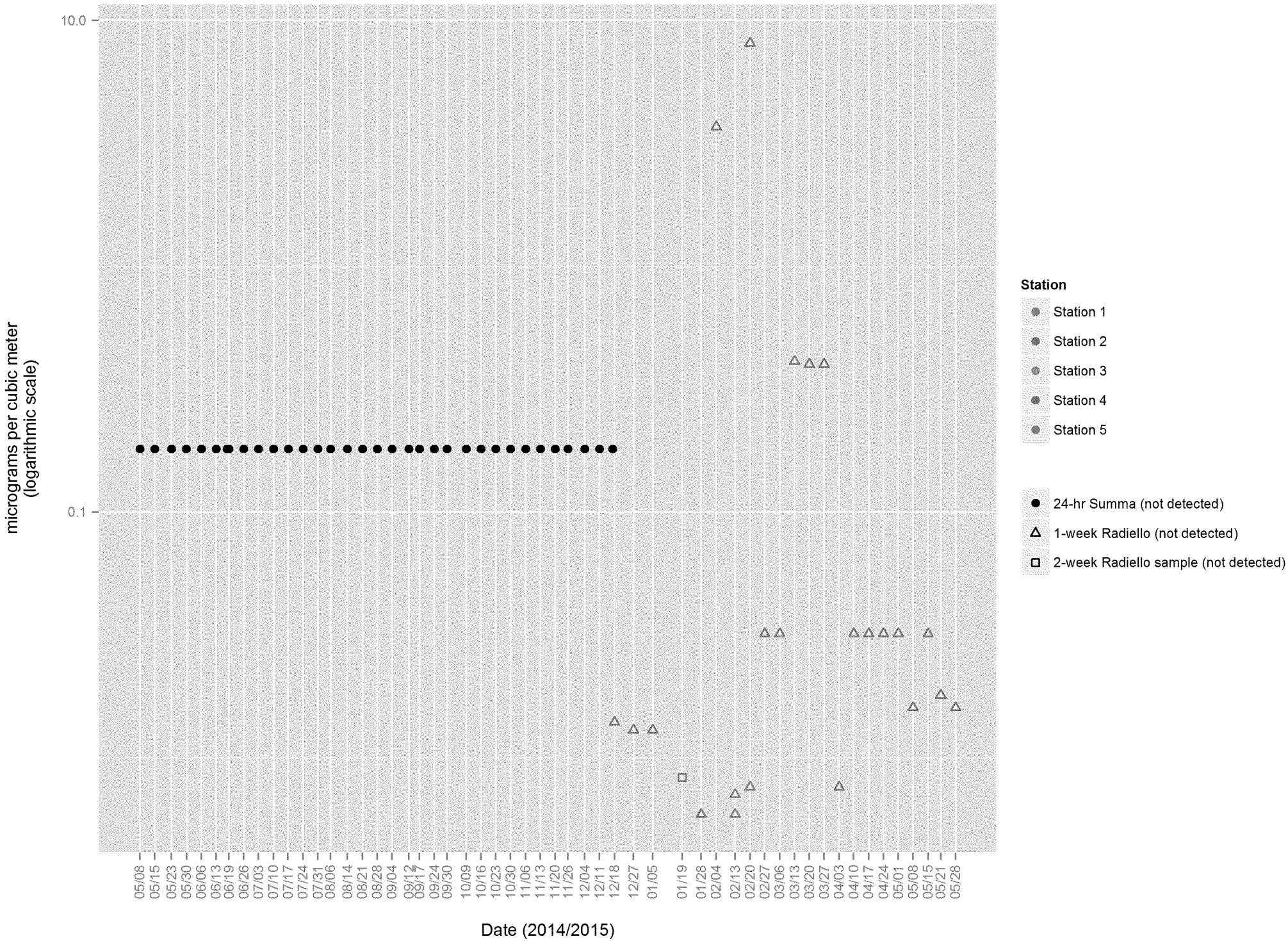


Exhibit C-15
Vinyl chloride



APPENDIX D

FREQUENCY OF DETECTION SUMMARY AND STATISTICAL ANALYSIS RESULTS

WLLFOIA4312 - 015 - 0154872

TABLE D-1
COMPARISON OF PASSIVE/DIFFUSIVE SAMPLING RESULTS AT OFF-SITE AIR MONITORING STATIONS
WEST LAKE LANDFILL, BRIDGETON, MISSOURI

Analyte[1]	Frequency of Detection[2]						Results of Statistical Comparison Among Off-Site WLLS Stations[3, 4]
	Station 1	Station 2	Station 3	Station 4	Station 5	Total	
Hydrogen Sulfide	58.3%	72.7%	45.5%	71.4%	63.6%	62.3%	No station tended to have larger or smaller measurements than any other (p-value = 0.07546)
Tetrachloroethene	41.7%	36.4%	36.4%	33.3%	27.3%	35.0%	No station tended to have larger or smaller measurements than any other (p-value = 0.2128)
m&p-Xylene	33.3%	27.3%	27.3%	33.3%	36.4%	31.5%	No station tended to have larger or smaller measurements than any other (p-value = 0.2222)
Trichloroethene	33.3%	45.5%	18.2%	19.0%	36.4%	30.5%	Difference detected among Stations 1-5, but a post-hoc analysis was inconclusive regarding pair-wise station-to-station comparisons. A plot of the data suggests Station 2 tended to have higher measurements than the other stations (p-value = 0.02623)
Ethylbenzene	33.3%	27.3%	27.3%	23.8%	27.3%	27.8%	No station tended to have larger or smaller measurements than any other (p-value = 0.3206)
o-Xylene	33.3%	27.3%	27.3%	23.8%	27.3%	27.8%	No station tended to have larger or smaller measurements than any other (p-value = 0.2526)
1,2,4-Trimethylbenzene	33.3%	18.2%	18.2%	14.3%	18.2%	20.4%	No station tended to have larger or smaller measurements than any other (p-value = 0.1257)
1,3,5-Trimethylbenzene	25.0%	18.2%	18.2%	19.0%	18.2%	19.7%	No station tended to have larger or smaller measurements than any other (p-value = 0.4653)
Methyl-tert-butyl ether	16.7%	18.2%	18.2%	19.0%	18.2%	18.1%	No station tended to have larger or smaller measurements than any other (p-value = 0.5283)
Isopropylbenzene (Cumene)	16.7%	18.2%	18.2%	14.3%	18.2%	17.1%	No station tended to have larger or smaller measurements than any other (p-value = 0.406)
Benzene	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*Analyte not detected*
cis-1,2-Dichloroethene	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*Analyte not detected*
Toluene	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*Analyte not detected*
trans-1,2-Dichloroethene	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*Analyte not detected*
Vinyl chloride	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*Analyte not detected*

Notes:

[1] Analytes listed in descending rank according to overall percent detection.

[2] Frequency of detection is the rate of analyte detection via laboratory analysis of the passive/diffusive samplers. Detection of an analyte in either the sample or its duplicate was counted as one detect.

[3] Results from the statistical software package R (version 3.2.0) using the non-parametric Friedman test to identify tendencies for measurements from one station to be larger or smaller than at any other station. A p-value equal to or greater than 0.05 suggests no tendency for one station to yield larger or smaller measurements than any other station. A p-value less than 0.05 suggests that one or more stations tended to yield measurements larger or smaller than other stations.

[4] Shading indicates detection of a difference.

APPENDIX E

OUTPUT FROM STATISTICAL ANALYSES

WLLFOIA4312 - 015 - 0154874

```
[1] "1,2,4-Trimethylbenzene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014   -1.0000     -1.00     -1.00     -1.00     -1.00
     12/27/2014   -1.0000     -1.00     -1.00     -1.00     -1.00
       1/5/2015   -1.0000     -1.00     -1.00     -1.00     -1.00
      1/19/2015   -1.0000     -1.00     -1.00     -1.00     -1.00
      1/28/2015    0.2600      0.27      0.32      0.30      0.45
       2/4/2015   -1.0000     -1.00     -1.00     -1.00     -1.00
      2/13/2015    0.1125      0.14      0.18      0.13      0.17
      3/13/2015   -1.0000     -1.00     -1.00     -1.00     -1.00

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 7.2, df = 4, p-value = 0.1257

[1] "1,3,5-Trimethylbenzene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014    -1.000    -1.000    -1.000    -1.000    -1.000
     12/27/2014    -1.000    -1.000    -1.000    -1.000    -1.000
       1/5/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      1/19/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      1/28/2015     0.110     0.100     0.110     0.094     0.130
       2/4/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      2/13/2015     0.042     0.046     0.054     0.046     0.056
      2/27/2015    -1.000    -1.000    -1.000    -0.445    -1.000
       3/6/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      3/13/2015    -1.000    -1.000    -1.000    -1.000    -1.000

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 3.5833, df = 4, p-value = 0.4653

[1] "Ethylbenzene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014     -1.00     -1.00     -1.00    -1.000     -1.00
     12/27/2014     -1.00     -1.00     -1.00    -1.000     -1.00
       1/5/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      1/19/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      1/28/2015      0.32      0.31      0.29     0.295      0.37
       2/4/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      2/13/2015      0.20      0.19      0.20     0.180      0.26
       3/6/2015      0.19      0.14      0.15     0.145      0.14
      3/13/2015     -1.00     -1.00     -1.00    -1.000     -1.00

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 4.6897, df = 4, p-value = 0.3206

[1] "Hydrogen Sulfide data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014      0.57      0.56      0.54     0.540      0.64
     12/27/2014      0.40      0.49      0.46     0.495      0.51
       1/5/2015      0.53      0.37      0.55     0.610      0.55
      1/19/2015      0.29      0.22      0.16     0.270      0.24
      1/28/2015      0.45      0.39      0.38     0.500      0.25
       2/4/2015      0.31      0.24     -1.00     0.280      0.26
      2/13/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      2/20/2015     -1.00      0.39     -1.00    -1.000     -1.00
      2/27/2015     -1.00     -1.00     -1.00    -1.000     -1.00
       3/6/2015     -1.00     -1.00     -1.00    -0.380     -1.00
      3/13/2015      0.24      0.48     -1.00     0.405      0.31
```

```
        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 8.481, df = 4, p-value = 0.07546

[1] "Isopropylbenzene (Cumene) data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014    -1.000    -1.000    -1.000   -1.0000    -1.000
     12/27/2014    -1.000    -1.000    -1.000   -1.0000    -1.000
       1/5/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      1/19/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      1/28/2015     0.028     0.025     0.023    0.0245     0.027
       2/4/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      2/13/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
       3/6/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      3/13/2015    -1.000    -1.000    -1.000   -1.0000    -1.000

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 4, df = 4, p-value = 0.406

[1] "m&p-Xylene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014     -1.00     -1.00     -1.00    -1.000     -1.00
     12/27/2014     -1.00     -1.00     -1.00    -1.000     -1.00
       1/5/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      1/19/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      1/28/2015      0.97      0.96      0.88     0.875      1.10
       2/4/2015     -1.00     -1.00     -1.00    -1.000     -1.00
      2/13/2015      0.50      0.49      0.52     0.460      0.65
       3/6/2015      0.44      0.35      0.38     0.350      0.36
      3/13/2015     -1.00     -1.00     -1.00     0.905      0.87

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 5.7067, df = 4, p-value = 0.2222

[1] "Methyl-tert-butyl ether data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014    -1.000    -1.000    -1.000    -1.000    -1.000
     12/27/2014    -1.000    -1.000    -1.000    -1.000    -1.000
       1/5/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      1/19/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      1/28/2015     0.022     0.023     0.024     0.025     0.029
       2/4/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      2/13/2015    -1.000    -1.000    -1.000    -1.000    -1.000
      2/27/2015     0.041     0.038     0.039     0.038     0.039
      3/13/2015    -1.000    -1.000    -1.000    -1.000    -1.000

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 3.1795, df = 4, p-value = 0.5283

[1] "o-Xylene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014     -1.00     -1.00     -1.00     -1.00     -1.00
     12/27/2014     -1.00     -1.00     -1.00     -1.00     -1.00
       1/5/2015     -1.00     -1.00     -1.00     -1.00     -1.00
      1/19/2015     -1.00     -1.00     -1.00     -1.00     -1.00
      1/28/2015      0.34      0.33      0.30      0.30      0.39
```

```
       2/4/2015     -1.00     -1.00     -1.00     -1.00     -1.00
      2/13/2015      0.18      0.18      0.19      0.17      0.24
       3/6/2015      0.16      0.14      0.14      0.13      0.13
      3/13/2015     -1.00     -1.00     -1.00     -1.00     -1.00

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 5.3571, df = 4, p-value = 0.2526

[1] "Tetrachloroethene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014    -1.000    -1.000    -1.000   -1.0000    -1.000
     12/27/2014    -1.000    -1.000    -1.000   -1.0000    -1.000
       1/5/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      1/19/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      1/28/2015     0.260     0.460     0.160    0.1800     0.230
       2/4/2015    -1.000    -1.000    -1.000   -1.0000    -1.000
      2/13/2015     0.125     0.120     0.120    0.1100     0.130
      2/27/2015     0.120     0.085     0.087    0.0845    -1.000
       3/6/2015     0.160     0.096     0.095    0.1050     0.085
      3/13/2015    -1.000    -1.000    -1.000   -1.0000    -1.000

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 5.8228, df = 4, p-value = 0.2128

[1] "Trichloroethene data for Friedman's Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
     12/18/2014   -1.0000     -1.00    -1.000    -1.000    -1.000
     12/27/2014   -1.0000     -1.00    -1.000    -1.000    -1.000
       1/5/2015   -1.0000     -1.00    -1.000    -1.000    -1.000
      1/19/2015   -1.0000     -1.00    -1.000    -1.000    -1.000
      1/28/2015    0.1000      0.51     0.110     0.150     0.087
       2/4/2015   -1.0000     -1.00    -1.000    -1.000    -1.000
      2/13/2015    0.0415      0.33     0.044     0.048     0.063
      2/27/2015   -1.0000      0.24    -1.000    -1.000     0.120
       3/6/2015   -1.0000      0.11    -1.000    -1.000    -1.000
      3/13/2015   -1.0000     -1.00    -1.000    -1.000    -1.000

        Friedman rank sum test

data:  as.matrix(testdata.wide[2:6])
Friedman chi-squared = 11.03, df = 4, p-value = 0.02623

Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2    12.5     19.84873      FALSE
1-3     2.0     19.84873      FALSE
1-4     4.0     19.84873      FALSE
1-5     4.0     19.84873      FALSE
2-3    10.5     19.84873      FALSE
2-4     8.5     19.84873      FALSE
2-5     8.5     19.84873      FALSE
3-4     2.0     19.84873      FALSE
3-5     2.0     19.84873      FALSE
4-5     0.0     19.84873      FALSE
```

APPENDIX F

MANUFACTURER DATASHEETS FOR SAMPLING EQUIPMENT

Volatile organic compounds (VOCs)

chemically desorbed with CS_2

Radiello components to be used:

White diffusive body code 120
Supporting plate code 121
Vertical adapter code 122 (optional)
Adsorbing cartridge code 130

Or: *radiello*-***ready-to-use*** **code 123-1 (also see page A8)**

Principle

Code 130 cartridge is a stainless steel net cylinder, with 100 mesh grid opening and 5.8 mm diameter, packed with 530 ± 30 mg of activated charcoal with particle size 35-50 mesh. Volatile organic compounds are trapped by adsorption and recovered by carbon disulfide displacement, analysis is performed by FID gas chromatography.

Sampling rates

The table on page D2 lists sampling rate values at 298 K (25 °C) and 1013 hPa, experimentally measured in a standard atmosphere chamber. For other compounds, whose diffusion coefficient[1] is known, sampling rate can be calculated according to equation [5] on page A2, taking into account that white diffusive body and code 130 cartridge give the geometric constant of radiello the value of 14.145 ± 0.110 cm. Several experiments performed in the standard atmosphere chamber demonstrate that the calculated sampling rates seldom deviate by more than ± 10% from the experimentally measured values.

Effect of temperaure, humidity and wind speed

Sampling rates varies from the value at 298 K on the effect of temperature (in Kelvin) as expressed by the following equation

$$Q_K = Q_{298} \left(\frac{K}{298}\right)^{1.5}$$

where Q_K is the sampling rate at the temperature **K** and Q_{298} is the reference value at 298 K. This produces a variation of ± 5% for 10 °C variation (upwards or downwards) from 25 °C.

Sampling rate is invariant with humidity in the range 15-90% and with wind speed between 0.1 and 10 $m \cdot s^{-1}$.

[1]Lugg G.A.: Diffusion Coefficients of Some Organic and Other Vapours in Air. *Anal. Chem.* **40-7**:1072-1077 (1968).

Calculations

The listed sampling rate values already take into account for the desorption efficiency with carbon disulfide. **The average concentration over the exposure time interval is therefore calculated from the mass of analyte found onto the cartridge and exposure time without introducing any corrective factor**, apart from corrections due to average temperature different from 25 °C.

Average concentration over the whole exposure time is calculated according to the following expression

$$C\ [\mu g \cdot m^{-3}] = \frac{m\ [\mu g]}{Q_K\ [ml \cdot min^{-1}] \cdot t\ [min]}\ 1{,}000{,}000$$

where:
m = mass of analyte in µg
t = exposure time in minutes

SUPELCO 595 North Harrison Road, Bellefonte, PA 16823 USA
www.sigma-aldrich.com/radiello

radiello is patented by
FONDAZIONE SALVATORE MAUGERI-IRCCS
Centro di Ricerche Ambientali - via Svizzera, 16 - 35127 PADOVA

Sampling rate values Q at 25°C (298 K)

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
acetone	77	10,000-600·10^6	7.0	a
acetonitrile	73	10,000-6·10^6	8.2	b
acrylonitrile	75	1,000-50·10^6	2.2	
benzyl alcohol	37	1,000-800·10^6	6.5	
amyl acetate	52	1,000-800·10^6	3.4	
benzene	80	500-500·10^6	1.8	
bromochloromethane	70	50,000-1,000·10^6	1.4	
butanol	74	1,000-500·10^6	5.0	
sec-butanol	64	1,000-300·10^6	5.2	
tert-butanol	62	1,000-300·10^6	5.5	
butyl acetate	60	1,000-1,000·10^6	3.0	
2-butoxyethanol	56	1,000-100·10^6	5.7	
2-butoxyethyl acetate	41	1,000-100·10^6	5.5	
carbon tetrachloride	67	100,000-60·10^6	9.0	
cyclohexane	54	500-500·10^6	4.5	
cyclohexanone	68	5,000-120·10^6	4.2	
cyclohexanol	54	5,000-120·10^6	4.5	
chlorobenzene	68	1,000-1,000·10^6	3.6	
chloroform	75	100,000-60·10^6	9.7	a
n-decane	43	500-1,000·10^6	1.1	
diaceton alcohol	43	500-1,000·10^6	4.5	
1,4-dichlorobenzene	51	1,000-1,000·10^6	7.7	
1,2-dichloroethane	77	1,000-500·10^6	8.2	
1,2-dichloropropane	66	500-250·10^6	4.5	
dichloromethane	90	500-60·10^6	8.7	
N,N-dimetylformamide	82	1,000-200·10^6	14.5	c
1,4-dioxane	68	1,000-600·10^6	5.5	
n-dodecane	8	1,000-1,000·10^6	4.7	
n-heptane	58	5,000-1,500·10^6	3.0	
n-hexane	66	1,000-1,000·10^6	2.5	
1-hexanol	52	5,000-120·10^6	5.5	
ethanol	102	10,000-500·10^6	7.5	a-b
diethyl ether	78	5,000-500·10^6	12.0	a
ethyl acetate	78	1,000-1,000·10^6	1.5	
ethylbenzene	68	1,000-1,000·10^6	2.4	
2-ethyl-1-hexanol	43	5,000-500·10^6	10.1	
2-ethoxyethanol	55	500-50·10^6	6.7	b
2-ethoxyethyl acetate	54	10,000-100·10^6	2.5	
ethyl-*tert*-butyl ether (ETBE)	61	500-200·10^6	3.0	
isobutanol	77	1,000-300·10^6	2.5	
isobutyl acetate	63	1,000-1,000·10^6	5.2	
isooctane	55	500-1,000·10^6	3.2	
isopropanol	52	10,000-400·10^6	12.0	b
isopropyl acetate	66	1,000-1,000·10^6	9.9	
isopropylbenzene	58	1,000-1,000·10^6	2.7	
limonene	43	1,000-1,000·10^6	10.0	
methanol	125	10,000-250·10^6	9.2	a-b
methyl acetate	80	1,000-1,000·10^6	12.0	
methyl-*ter*-butyl ether (MTBE)	65	500-200·10^6	2.5	

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
methylcyclohexane	66	1,000-1,000·10^6	6.5	
methylcyclopentane	70	1,000-1,000·10^6	2.5	
methylethylketone	79	1,000-500·10^6	1.6	
methylisobutylketone	67	1,000-250·10^6	8.7	
methyl metacrylate	68	1,000-500·10^6	2.5	
2-methylpentane	70	1,000-1,000·10^6	2.5	
3-methylpentane	70	1,000-1,000·10^6	2.5	
2-methoxyethanol	35	5,000-100·10^6	11.0	b
2-methoxyethyl acetate	56	2,000-100·10^6	3.0	
1-methoxy-2-propanol	55	1,000-350·10^6	6.0	
1-methoxy-2-propyl acetate	60	2,000-350·10^6	6.2	
naphthalene	25	1,000-1,000·10^6	7.0	
n-nonane	48	1,000-1,000·10^6	5.4	
n-octane	53	500-1,000·10^6	3.2	
pentane	74	1,000-1,000·10^6	1.9	
α-pinene	53	1,000-1,000·10^6	7.0	
propyl acetate	65	500-1,000·10^6	7.5	
propylbenzene	57	1,000-1,000·10^6	2.9	
styrene	61	1,000-500·10^6	3.0	
tetrachloroethylene	59	10,000-500·10^6	2.5	
tetrahydrofuran	74	2,000-250·10^6	11.0	b
toluene	74	500-1,000·10^6	1.5	
1,1,1-trichloroethane	62	5,000-1,000·10^6	5.5	
trichloroethylene	69	5,000-1,000·10^6	2.4	
1,2,4-trimethylbenzene	50	500-1,000·10^6	6.6	
n-undecane	24	1,000-1,000·10^6	10.0	
m-xylene	70	500-1,000·10^6	2.5	
o-xylene	65	500-1,000·10^6	2.5	
p-xylene	70	500-1,000·10^6	2.5	

Notes:

a = weakly adsorbed compound. If its concentration is higher than the TLV for the workplace environments it may be partially displaced by other compounds that are more strongly trapped if their concentration is also high. If this is the case, it is advisable to reduce sampling time under 8 hours.

b = prolonged exposure of charcoal cartridges at relative average humidity higher than 80% causes adsorption of up to 100 mg of water. Water does not interfere with adsorption mechanisms but is displaced by carbon disulfide and gives raise to a separate layer. Some very water soluble polar compounds will distribute between the two solvents, thus provoking an underestimation of the actual air concentration since only the carbon disulfide is injected in the gas chromatograph. When the concentration of polar compounds has to be determined, the calibration curve should be prepared by spiking 50 µl of water in each tube containing the cartridge and the 2 ml of carbon disulfide standard solution (see Analysis).

c = better reproducibility obtained by use of methanol as extraction solvent instead of carbon disulfide.

Limit of quantitation

The limit of quantitation depends on the instrumentation and on the analytical conditions. The minimum revealable environmental concentration can be estimated on the basis of the equation on page D1, where ***m*** is the minimum revealable mass, experimentally measured for each compound. Under the analytical conditions described on page D4, the limit of quantitation for 7 days exposure usually ranges from 0.05 to 1 µg·m^{-3}, depending on the compound.

Exposure

Code 130 cartridge has a very large loading capacity: about 80 mg, corresponding to an overall VOCs concentration of 3,000-3,500 mg·m^{-3} sampled for 8 hours or 70,000-80,000 µg·m^{-3} sampled for 14 days. Neverthless, if the quantified overall adsorbed mass should be near 80 mg, sampling rate could have deviated from linearity. If this is the case, it is advisable to repeat the sampling experiment reducing exposure time.

Workplace environment

In workplace environments complex mixtures of airborne solvent vapours are often found at concentrations of 2,000-3,000 mg·m^{-3}. The outstanding adsorbing capacity of code 130 cartridges allows you to sample them for the whole working shift of 8 hours. On the other hand, the very high values of sampling rates for a variety of compounds allow you to perform accurate concentration measurements even after very short exposures. For example, 15 minutes are enough to measure 0.1 mg·m^{-3} of benzene.

radiello can therefore be employed to evaluate both *TWA* and *STEL* concentrations.

Other indoor sampling experiments and outdoor campaigns

High sampling rates of ***radiello*** ensure very low limits of detection also for short exposure time intervals. For example, you may measure benzene concentrations as low as 2 µg·m^{-3} with an error not exceeding 4% after 8 hours of exposure. If ***radiello*** is exposed for 7 days, limit of quantitation becomes 0.1 µg·m^{-3}.

Generally speaking, we suggest exposure time duration ranging from 8 hours to 30 days, the ideal value being 7 days.

Storage

The activated charcoal cartridges have undergone a complex conditioning process that ensures an outstanding chromatographic blank level, never exceeding three times the instrumental noise of a FID detector at the lowest attenuation.

Kept in a cool place and away from volatile organic compounds, the cartridges mantain unchanging blank level and adsorbing capacity for at least two years. Expiry date and lot number are printed onto the plastic bag wrapping each cartridge: its integrity stands as warranty seal.

After exposure the cartridges, well capped and kept in a cool and solvent-free place, mantain their content unalterated for at least six months.

Analysis

Extraction

Introduce 2 ml of CS_2 and 100 µl of internal standard solution (see next page) directly in the ***radiello*** glass tube without drawing out the cartridge. **Always use class A volumetric pipettes or dispensers.** Stir from time to time for 30 minutes. If analysis is not performed soon after, draw out the cartridge and discard it.

Calibration

Outdoor environment sampling

If benzene, toluene, ethylbenzene and xylenes (BTEX) have to be analyzed, prepare three or four standard solutions in CS_2 having decreasing concentrations of the analytes in the following ranges (in mg·l^{-1}):

benzene	0.04-17.6	ethylbenzene	0.04-17.7
toluene	0.09-34.8	m-xylene	0.04-17.2
o-xylene	0.04-17.6	p-xylene	0.04-17.2

It is advisable to proceed via consecutive dilutions, starting for example from a stock solution containing 1 ml of each compound in 100 ml. Always use class A volumetric glassware. Introduce 2 ml of each standard solution, along with 100 µl of internal standard, onto a blank code 130 cartridge in its glass tube.

IMPORTANT

always use high purity grade CS_2, for example Fluka Cat. No. 84713 or Aldrich Cat. No. 34,227-0

BE CAREFUL

even refrigerated, CS_2 permeates the tube plastic cap: its volume decreases by 4-5% a day. If the internal standard has been added, it is only matter of unpleasant odour...

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Analysis of unknown samples

Identify the sample that has been exposed for the longest time or at the highest expected concentration. Introduce 2 ml of CS_2 but do not add the internal standard, stir and let the sample stand for 30 minutes. Without discarding the cartridge, inject the CS_2 solution in the gas chromatograph with FID detector (see below), identify the compounds appearing in the chromatogram and make an estimation of the order of magnitude of their concentrations.

USER TIP

For a very accurate calibration we offer the **preloaded cartridges code 405** (outdoor environment) and **code 406** (workplace environment).

Prepare a CS_2 solution of the identified compounds with doubled concentration with respect to the sample. Dilute this solution in order to obtain standard solutions of concentration respectively about 0.1, 0.5 and 1 times the concentration estimated in the sample. Introduce 2 ml of each standard solution onto a blank code 130 cartridge in its glass tube, along with the chosen internal standard solution.

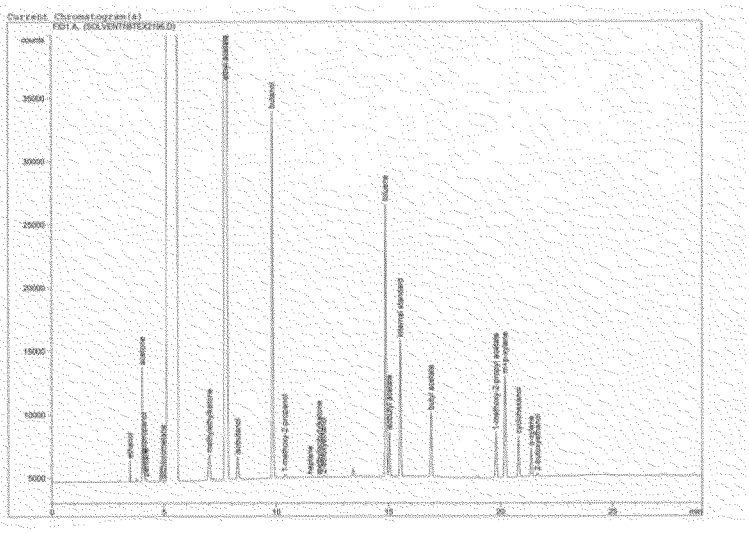
The chosen **internal standard** should have a retention time that does not interfere with other compounds in the chromatogram. Compatibly with this requirements, we suggest to employ a solution of **2-fluorotoluene** (e.g. Aldrich F 1,532-3 or Fluka 47520) in CS_2 with concentration of 100 $\mu l \cdot l^{-1}$ for outdoor samples and 2 $ml \cdot l^{-1}$ for workplace samples. Add 2 ml of CS_2 and the internal standard to all of the samples, stir, let the samples stand for 30 minutes and discard the cartridges prior to the analysis.

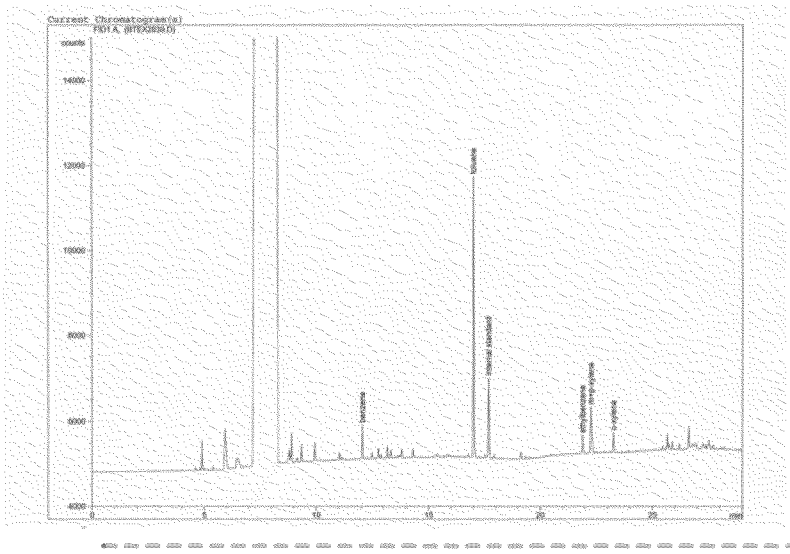
Instrumental analysis (advised)

Capillary gas chromatography with FID detection

outdoor environment samples: 100% dimethylpolysiloxane column 50m x 0.2mm, film thickness 0.5 µm; (e.g. Petrocol DH 50.2, Supelco Cat.No. 24133-U) split injection of 2 µl; split ratio 25:1; nitrogen carrier gas at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 35 °C for 5 minutes, 5 °C/min up to 90 °C, maintain for 3 minutes, 10 °C/min up to 220 °C, final isotherm for 5 minutes.

workplace samples: 100% dimethylpolysiloxane column 0.2 mm·50 m, film 0.5 µm; split injection of 3 µl, split ratio 100:1; carrier N_2 at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 50 °C for 5 minutes, 5 °C/min up to 80 °C, 15 °C/min up to 135 °C, 20 °C/min up to 220 °C, final isotherm 10 minutes. Total time: 29 minutes. The retention times for several compounds analyzed under the described conditions are listed in the table on next page.





On top: *FID chromatogram of a real workplace sample*

on the left: *chromatogram of a real urban outdoor sample*

USER TIP

If you perform several analyses, a barcode reader will greatly improve productivity in your laboratory and will also minimize the possibility of errors in the copying of sample labels.

Please contact us to help you in the implementation of the reader.

We have also developed software solutions for the analytical data processing and automated production of analysis reports.

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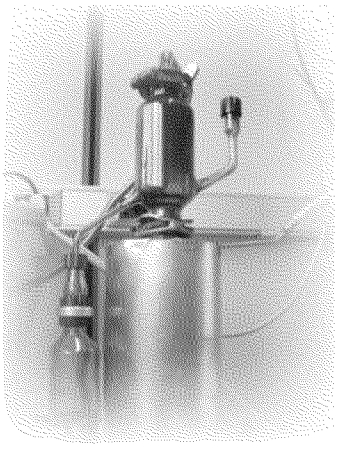
What makes the code 130 cartridge incomparable?

	retention time (minutes)
methanol	4.834
ethanol	5.340
acetone	5.712
isopropanol	5.835
pentane	6.121
methyl acetate	6.346
dichloromethane	6.405
2-methylpentane	7.559
methylethylketone	7.719
3-methylpentane	7.941
ethyl acetate	8.331
n-hexane	8.402
isobutanol	8.763
methylcyclopentane	9.350
1,1,1-trichloroethane	9.636
butanol	9.956
isopropyl acetate	9.978
benzene	10.203
1-methoxy-2-propanol	10.424
cyclohexane	10.580
1,2-dichloropropane	11.285
trichloroethylene	11.625
isooctane	11.667
2-ethoxyethanol	11.831
propyl acetate	11.868
n-eptane	12.068
1-ethoxy-2-propanol	12.775
methylcyclohexane	12.912
methylisobutylketone	13.258
isobutyl acetate	14.005
toluene	14.055
butyl acetate	15.279
n-octane	15.435
tetrachloroethylene	15.601
diaceton alcohol	15.915
1-methoxy-2-propyl acetate	16.609
ethylbenzene	16.997
m+p-xylene	17.241
cyclohexanone	17.436
cyclohexanol	17.436
styrene	17.716
o-xylene	17.832
2-buthoxyethanol	17.880
n-nonane	18.186
α-pinene	19.129
n-decane	20.334
n-undecane	22.142



the container

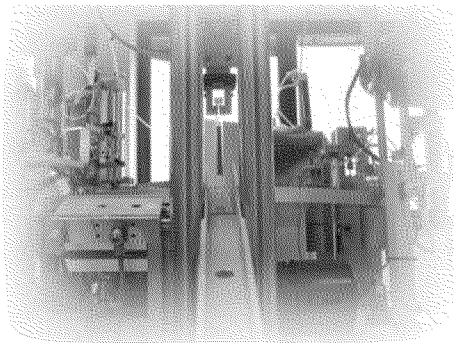
The container is made of stainless steel cloth AISI 316 with 100 mesh grid opening. It is electric welded with no supply of foreign materials. It has tolerance of ± 0.05 mm diameter and of ± 0.1 mm length.

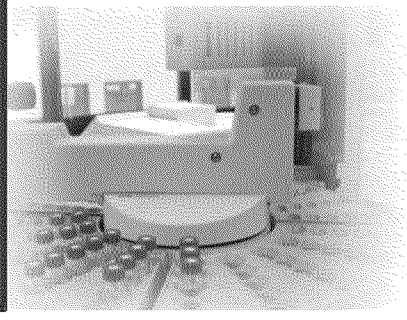
the contents

The cartridge is packed with vegetal activated charcoal with a very large adsorbing surface. Its exceptionally low blank is obtained by conditioning it in a nitrogen stream fluidised bed at 450 °C for 16 hours. The fluidised bed technique does not only guarantee the thorough purification of adsorbing material but also performs an accurate selection of its granulometry, by ventilation separations of the fraction under 50 mesh and over 35 mesh.

the production

The cartridge is filled up with charcoal by a very complex automated apparatus that was designed and realised in our laboratory. It avoids any contamination of the adsorbing material during the delicate process of cartridge production and ensures a very accurate dosing of the material itself, providing a variability of less than 2% of the weight of the activated charcoal among the cartridges.





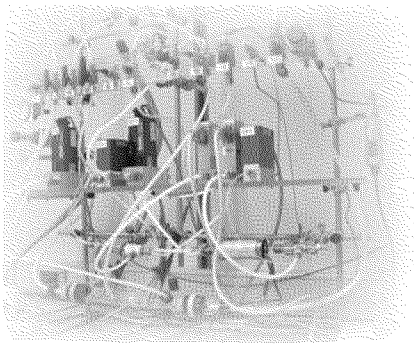
the quality control

Each cartridge batch undergoes statistical quality control of the blank level. If amounts higher than 20 ng of each of the BTEX compounds are found, the entire lot is discarded.

the sampling rate measurements

The sampling rate is measured in a standard atmosphere chamber unique in Italy (and one of the few found all over Europe) that allows the dynamic generation of high flows of controlled concentration gas mixtures from 1 $\mu g \cdot m^{-3}$ to 1,000 $mg \cdot m^{-3}$ (dynamic range from 1 to 10^6) of each investigated compound alone or mixed with others. The chamber allows temperature control from -20 to 60 °C, relative humidity control from 5% to 100% and air speed variation from 0.1 to 10 $m \cdot s^{-1}$.

All of the gas flows are measured as mass flows and have therefore the properties of primary standards. All of the operating parameters (gas flows, temperature, relative humidity, ...) are recorded and the records are available along with the certification documents.



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SUPELCO

Volatile organic compounds (VOCs)

thermally desorbed

Radiello components to be used:

Yellow diffusive body code 120-2
Supporting plate code 121
Vertical adapter code 122 (optional)
Adsorbing cartridge code 145

Or: ***radiello*-ready-to-use code 123-2 (also see page A8)**

Principle

Code 145 is a stainless steel net cylinder, with 3x8 µm mesh grid opening and 4.8 mm diameter, packed with 350 ± 10 mg of graphitised charcoal (Carbograph 4), particle size is 35-50 mesh.

Volatile organic compounds are trapped by adsorption and recovered by thermal desorption, analysis is performed by capillary gas chromatography and FID or MS detection.

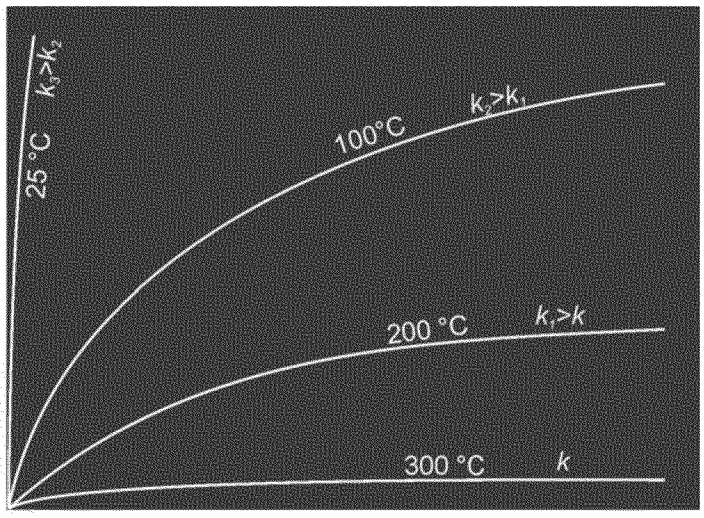
General considerations

Thermal desorption is an easy-to-use technique, but it implies some precautions and is of less general use than chemical desorption.

The recovery of adsorbed compounds is based onto the different shape of adsorption isotherms at different temperatures. Since quantitative desorption of trapped molecules should ideally be accomplished at moderate temperatures, only weak adsorbing media are employed, with active adsorbing surface between 10 and 50 times smaller than that of activated charcoal.

Use of thermal desorption requires therefore an accurate preliminary investigation about the adsorbed compound - adsorbing medium pair. Stronger adsorbents are suitable for very volatile compounds, but will yield only partial desorption of heavier compounds.

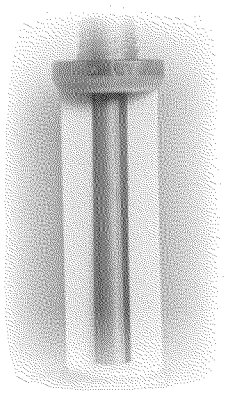
Anyway, *backdiffusion* (see page A3) is always lying in wait: due to the adsorbing medium weakness heavier compounds will eventually displace the more volatile ones. Once you have made an accurate choice of the adsorbing material, therefore, you should bear in mind that a real atmosphere is composed by a variety of compounds apart from those you are analyzing at unpredictable concentrations. As a consequence, sampling times can not be as long as those allowed by activated charcoal, otherwise lighter compounds will be lost. With the purpose of allowing reasonable sampling times (up to two weeks) the sampling rate has been dramatically reduced by changing the diffusive body from the white type (code 120) to the yellow one (code 120-2).



When in contact with a solid adsorbing medium, a gaseous compound will be adsorbed following the Freundlich isotherm, that is to say the adsorbed mass will be $x/m=kC^{1/n}$, where x is the mass of gaseous compound adsorbed by the mass m of the solid adsorbent and C is the concentration of the gaseous compound at the equilibrium in the gas phase. K and n depend on temperature and on the adsorbate - adsorbing medium pair. K increases with decreasing temperature and n is the closer to 1 the stronger the adsorbent.

At low temperatures, x/m depends almost linearly on the concentration in air (see the curve at 25 °C): this allows diffusive sampling. At high temperatures, the adsorbent mass is very low whatever the concentration in the gas phase: this allows the recovery of adsorbed compounds by heating (see the curve at 300 °C).

To ensure the best possible recovery yields, k and n have to be small. This, however, will compromise sampling efficiency. In other words, compounds strongly adsorbed at room temperature will be only partially recovered by thermal desorption. On the other hand, compounds that are easily desorbed by heating will be sampled at room temperature with low efficiency.



Smaller average pore size and thicker diffusive membrane make the diffusive path longer and, as a consequence, sampling rates are reduced to less than one third compared to those obtained with white diffusive bodies.

Some compounds, moreover, are thermally unstable. Thermal degradation of such compounds will cause an underestimation of their concentration or the appearance of ghost peaks.

Thermal desorption is neverthless an outstanding analytical technique because it is easy to perform, it does not require the use of toxic solvents as carbon disulfide, it ensures very low limits of detection, is suited to mass spectrometric detection and allows the recovery of the adsorbing cartridges. Basing on our experience, we have chosen Carbograph 4 as the best compromise between sampling efficiency and recovery yields for a wide range of organic compounds.

Sampling rates

Sampling rate values at 298 K (25 °C) and 1013 hPa are listed in table on page *E3*. All of the values shown have been experimentally measured. Exposure tests have been performed up to the levels shown (in $\mu g \cdot m^{-3} \cdot min$) and sampling rates are guaranteed to be linear up to the limit values and for overall concentration of volatile organic compounds in air not exceeding 2,000 $\mu g \cdot m^{-3}$.

Effect of temperature, humidity and wind speed

Sampling rates varies from the value at 298 K on the effect of temperature (in Kelvin) as expressed by the following equation

$$Q_K = Q_{298} \left(\frac{K}{298}\right)^{1.5}$$

where Q_K is the sampling rate at the temperature **K** and Q_{298} is the reference value at 298 K. This produces a variation of ± 5% for 10 °C variation (upwards or downwards) from 25 °C.

Sampling rate is invariant with humidity in the range 15-90% and with wind speed between 0.1 and 10 $m \cdot s^{-1}$.
Do not expose directly ***radiello*** to rain: even if only small amounts of water are adsorbed by Carbograph 4, they can nevertheless interfere with the analysis.

Calculations

The listed sampling rate values take already into account the recovery yields of adsorbed compounds. **The average concentration over the sampling period is therefore calculated from sampled mass of analyte and exposure time without introducing any other corrective factor,** apart from temperature variations of Q.

Average concentration ***C*** in $\mu g \cdot m^{-3}$ over the whole exposure time is calculated according to the following expression:

$$C\ [\mu g \cdot m^{-3}] = \frac{m\ [\mu g]}{Q_K\ [ml \cdot min^{-1}] \cdot t\ [min]}\ 1{,}000{,}000$$

where:
m = mass of analyte in µg
t = exposure time in minutes

Exposure

Workplace environment

The weaker adsorbent Cabograph is not recommended for workplace measurements, as high concentrations, that can be expected, would overload the sorbent. A stronger adsorbent, like activated charcoal, is needed (see page D1)

Other indoor sampling experiments and outdoor campaigns

Thermal desorption is exceptionally suited for long exposure times at low concentrations, as in outdoor campaigns and some indoor environments (e.g. homes, schools, etc...), particularly if the subsequent analysis is performed by HRGC-MS.

The recommended exposure times range from 8 hours to the upper limits shown in the table below. It is advisable to reduce sampling time if the estimated overall VOCs concentration is higher than 2,000 $\mu g \cdot m^{-3}$.

Sampling rate values Q at 25°C (298 K)

	Q_{298} $ml \cdot min^{-1}$	exposure time upper limit (days)	linear up to $\mu g \cdot m^{-3} \cdot min$	uncertainty (2σ) %	limit of detection[1] $\mu g \cdot m^{-3}$
benzene	27.8	7	410,000	8.3	0.05
benzene	26.8	14	410,000[2]	7.5	0.05
butyl acetate	24.5	14	580,000	12.4	0.05
2-butoxyethanol	19.4	14	550,000	9.7	0.1
cyclohexane	27.6	7	470,000	14.7	0.1
n-decane	22.3	14	450,000	22.4	0.1
1,4-dichlorobenzene	22.0	14	650,000	9.5	0.1
dimethyl disulfide	23.7	7	500,000	9.1	0.04
n-heptane	25.3	14	420,000	7.6	0.05
n-hexane	25.5	7	420,000	10.9	0.05
ethylbenzene	25.7	14	550,000	9.1	0.01
2-ethyl-1-hexanol	14.3	14	550,000	17.4	0.07
2-ethoxyethanol	26.0	14	570,000	7.7	0.05
2-ethoxyethyl acetate	20.9	14	600,000	8.0	0.05
isopropyl acetate	25.8	7	540,000	9.6	0.1
limonene	12.8	14	550,000	24.8	0.2
2-methoxyethanol	4.0	7	1,000,000	--	1.0
2-metoxyethyl acetate	21.0	7	1,000,000	--	0.1
1-methoxy-2-propanol	26.6	7	600,000	11.6	0.2
n-nonane	21.0	14	440,000	11.8	0.07
n-octane	24.1	14	440,000	13.4	0.07
α-pinene	6.4	14	550,000	29.5	0.2
styrene	27.1	14	550,000	24.0	0.01
tetrachloroethylene	25.4	7	1,000,000	8.9	0.02
toluene	30.0	14	550,000	8.3	0.01
1,1,1-trichloroethane	20.0	7	300,000	13.0	0.1
trichloroethylene	27.1	7	800,000	9.5	0.02
1,2,4-trimethylbenzene	21.9	14	550,000	9.6	0.05
n-undecane	12.0	14	520,000	32.7	0.05
m-xylene	26.6	14	550,000	11.3	0.01
o-xylene	24.6	14	550,000	9.1	0.01
p-xylene	26.6	14	550,000	11.3	0.01

[1]after 7 days exposure and with MS detection; analytical conditions as described in the Analysis paragraph

[2]for overall VOCs concentrations not exceeding 500 $\mu g \cdot m^{-3}$

Storage

The cartridges have undergone a complex conditioning procedure that ensures an outstanding chromatographic blank level. If kept in a cool place without VOCs contamination, blank level and adsorbing capacity stay unaltered for at least eighteen months.

After exposure the cartridges, well capped and kept in a cool and solvent-free place, are stable for at least three months.

Analysis

The analytical methods hereafter described have been set up with the Perkin-Elmer Turbomatrix thermal desorber and Agilent 5973 MSD mass spectrometer detector. They may be implemented on other instruments by introducing minor adjustements as suggested by the analyst's experience and characteristics of employed instrumentation.

In the following we propose two methods, one for **BTEX** analysis and another for **VOCs**. The former is suited to outdoor sampling in urban monitoring, where investigation is usually focussed onto benzene, toluene, ethylbenzene and xylene isomers. The latter is conceived for indoor monitoring, allowing quantification of all the compounds listed on page E3 and also extended qualitative analysis. The two methods differ by a few details, such as the higher desorption temperature for VOCs and the higher cryofocusing temperature for BTEX. The latter caution is introduced to avoid freezing of excess humidity gathered during the sampling in the cryofocusing trap.

Desorption

The thermal desorber is equipped with 1/4" OD SS sample tubes, they have to be hollow and free: discard the stainless steel gauze disk which is fitted to the groove and discard also the springs if present.

Code 145 cartridge has been dimensioned to fit the diameter of Turbomatrix thermal desorption tubes. Its length is such that, when the cartridge is introduced into the tube and is stopped by the groove, it is positioned exactly centrally with respect to the tube length.

Inner diameter of Perkin-Elmer tubes is not always exactly the same; it may be the case therefore that a cartridge code 145 does not slide easily into the tube. Some pushing tool may be helpful then, such as a 500 µl syringe piston, a glass bar or an iron wire 2-3 mm thick.

In some cases the tube inner diameter is sligthly larger than the cartridge outer diameter: the cartridge can therefore be pushed out from the tube during desorption due to the desorption gas pressure. If this is the case, make use of the springs provided along with the tubes.

Once capped, the Turbomatrix steel tube has to be positioned in the carousel with the grooves on the bottom.

The described conditions have been optimized for seven days exposures to typical concentrations of urban atmospheres and indoor environments. Shorter exposure times or considerably higher concentrations would require different settings of split flows, with the purpose of ensuring good analytical sensitivity or linearity of response.

Usually, the cartridge enters into the Turbomatrix tube by simple pouring. If it does not occur, use a pushing tool to press the cartridge till the nick on the tube.

BTEX

Temperatures and timing

- Desorption: 320 °C for 10 minutes
- Cryofocusing trap (Tenax TA): during primary desorption manitain 2 °C, secondary desorption at 99 °C/sec up to 290 °C, 1 minute at 290 °C
- Six port valve: 150 °C
- Transfer line: 200 °C

Flows

- Carrier gas: helium, 24 psi
- Desorption flow: 100 ml·min^{-1}
- Inlet split: 90 ml·min^{-1}
- Outlet split: 30 ml·min^{-1}

VOCs

Temperatures and timing

- Desorption: at 370 °C for 15 minutes
- Cryofocusing trap (Tenax TA): during primary desorption maintain at -20 °C, secondary desorption at 99 °C/sec up to 290 °C, 1 minute at 290 °C
- Six port valve: 150 °C
- Transfer line: 200 °C

Flows

- Carrier gas: helium, 24 psi
- Desorption flow: 100 ml·min^{-1}
- Inlet split: 90 ml·min^{-1}
- Outlet split: 30 ml·min^{-1}

Instrumental analysis

Analytical parameters for BTEX and VOCs are the same, apart from the duration of chromatographic run and final temperature.

We recommended the following conditions:

Column

100% dimethylpolysiloxane, length 50m x 0.2.mm, film thickness 0.5 µm; (e.g. Petrocol DH 50.2, Supelco Cat.No. 24133-U) the column is directly fitted to the six-port valve of Turbomatrix apparatus.

USER TIP

If you perform several analyses, a barcode reader will greatly improve productivity in your laboratory and will also minimize the possibility of errors in the copying of sample labels.

Please contact us to help you in the implementation of the reader.

We have also developed software solutions for the analytical data processing and automated production of analysis reports.

Temperatures

ffi GC oven: 40 °C for 3 minutes, 8 °C/min up to 80 °C, mantain for 1 minute, 20 °C/min up to 250 °C for BTEX and up to 280 °C for VOCs, final isotherm 1.5 minutes for BTEX and 3 minutes for VOC

ffi GC-MS interface: 270 °C

Flows

ffi Carrier gas: helium, 0.8 ml·min^{-1}

USER TIP

For a very accurate BTEX calibration we offer the **preloaded cartridges code 407.**

On page E6 we display two total ion current chromatograms from an outdoor urban site and an indoor sampling respectively.

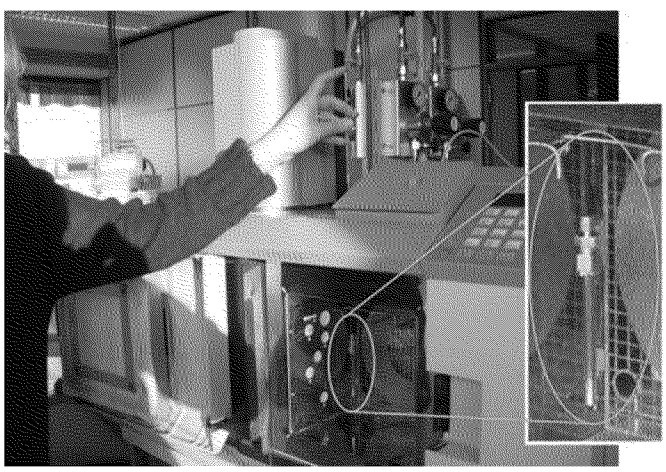
In the first case, the benzene peak corresponds to an average concentration of 2.2 µg·m^{-3}; in the second the concentration of 1,4-dichlorobenzene was 14 µg·m^{-3}. Despite the low concentration values, the signal-to-noise ratio is very high in both cases. As a consequence, very reliable mass spectral identification is possible.

Calibration

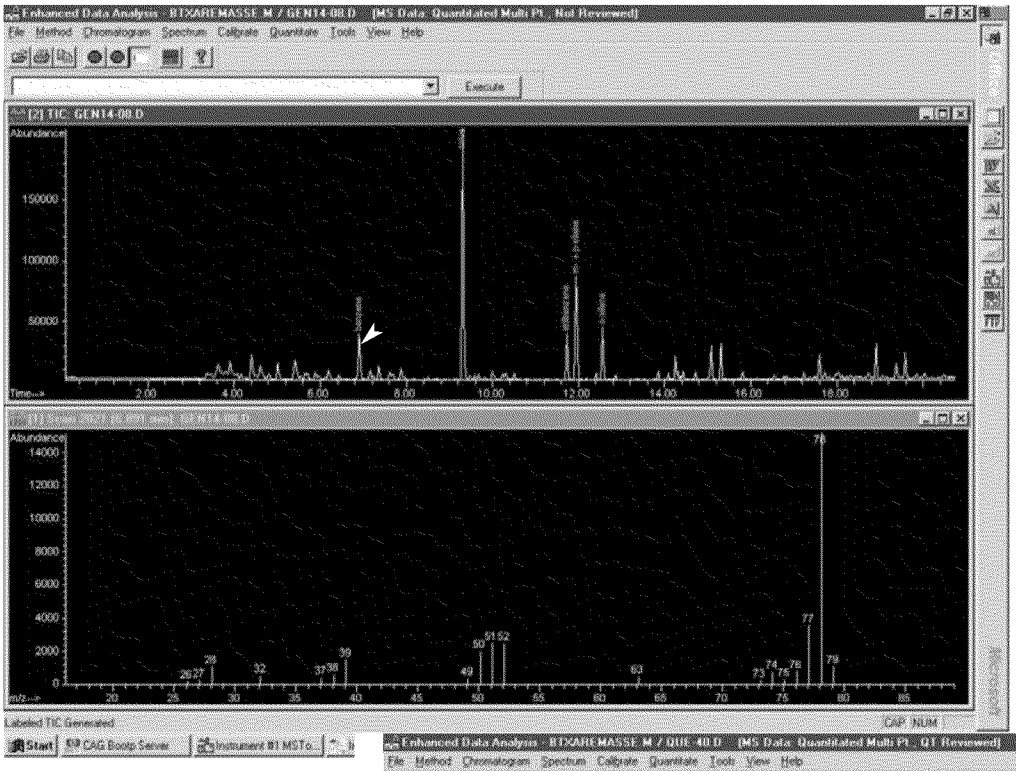
Calibration curves are obtained by gas-phase injection of methanol solutions of the target compounds onto blank cartridges. Injections are performed through a GC injector, where a short piece (10 cm) of wide-bore (0.53 i.d.) deactivated uncoated column is installed. The other end bears a Swagelock reducing connection (1/16"-1/4"). The 1/4" Swagelock nut has to be equipped with a PTFE *ferrule* instead of the original steel one (use PTFE ferrules that come along with the Turbomatrix caps).

Introduce a blank cartridge in a Turbomatrix tube and fit the tube to the Swagelock nut. Mantain the injector at 200 °C but do not heat the oven. Inject slowly 1 µl of each calibration solution under nitrogen flow (50 ml/min) and let the system purge for 2 minutes. Analyze the cartridge as you would do with a sample.

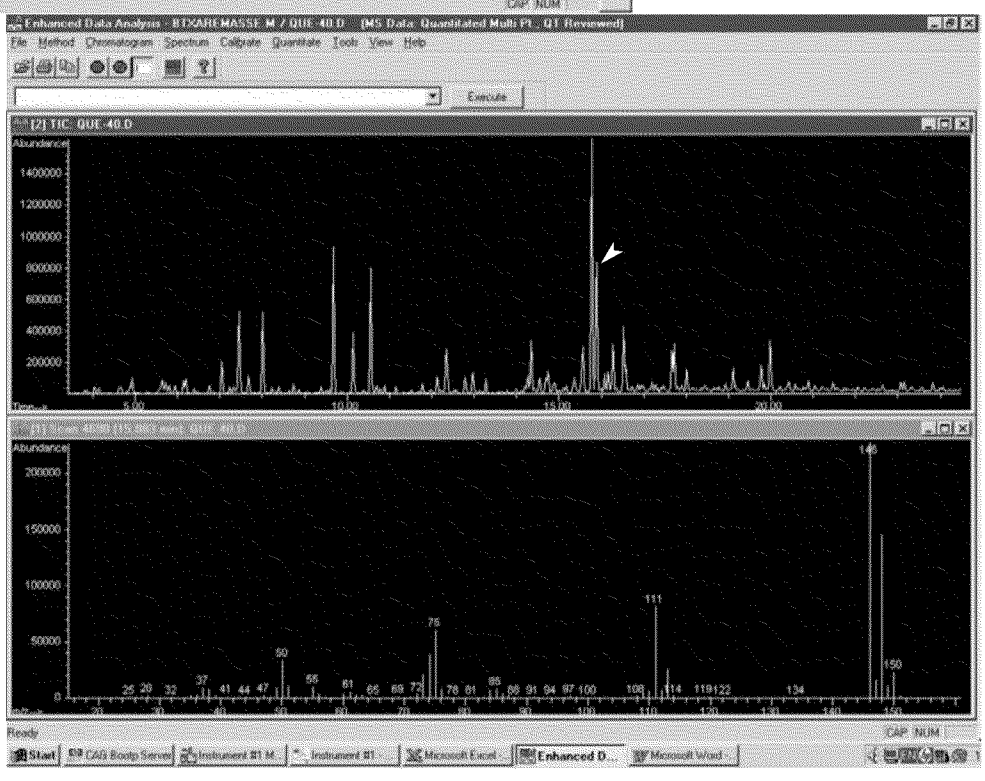
We suggest you to prepare a complete set of calibration solutions by subsequent dilutions such as they contain, for example, 8, 4, 2, 1, 0.04, 0.02 and 0.01 µg·µl^{-1} of each compound.



To prepare the calibration standards fit a 1/16"-1/4" Swagelock reducing connection to the GC injector by a short piece (10 cm) of wide-bore deactivated uncoated column.



TIC chromatograms of an outdoor urban sampling (left) and of indoor air (bottom). Mass spectra of benzene and of 1,4-dichlorobenzene are shown on the bottom of each picture, at concentrations of 2.2 and 14 µg·m^{-3} respectively. Despite the low concentration values, the signal-to-noise ratio is very high in both cases.
As a consequence, very reliable mass spectral identification is possible by comparison with mass spectral data libreries with no need of further processing.



Cartridge recovery

In principle, the thermal desorption analysis leaves a conditioned cartridge that can be used as it is for another sampling. Actually this is not the case since the desorption yield, even if very high, is never quantitative, particularly for compounds with more than six carbon atoms. We recommende therefore to re-condition the cartridges after analysis, keeping them at 350 °C for eight hours under nitrogen flow.

Graphitized charcoal is a fragile material that exhibits a tendency to turn to dust under mechanical stress during the use on field and in the laboratory. Even if the stainless steel net mesh grid opening is a few micrometers, dust is lost anyway and the cartridge will eventually become empty. As soon as the mass of graphitized charcoal is reduced by 20% the cartridge has to be discarded. Basing onto our experience, this will occur after at least twenty sampling-and-analysis cycles.

Hydrogen sulfide (H_2S)

Radiello components to be used

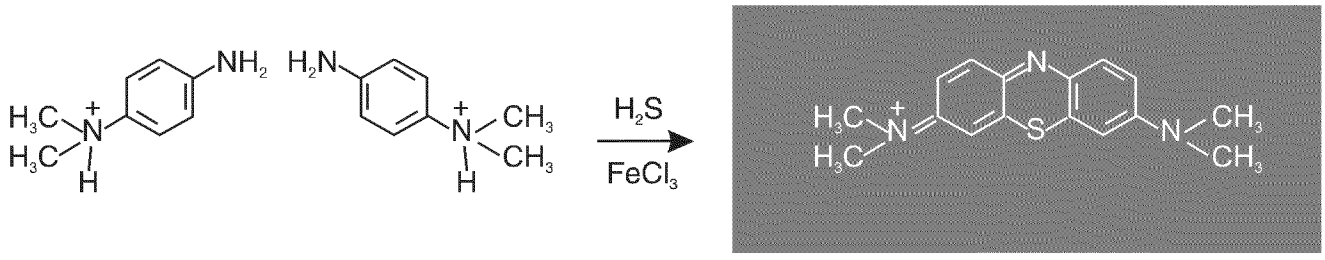
White diffusive body code 120
Supporting plate code 121
Vertical adapter code 122 (optional)
Chemiadsorbing cartridge code 170

Or: ***radiello-ready-to-use*** **code 123-6 (also see page A8)**

Principle

The cartridge code 170 is made of microporous polyethylene and impregnated with zinc acetate. Hydrogen sulphide is chemiadsorbed by zinc acetate and transformed into stable zinc sulfide.

The sulfide is recovered by extraction with water. In contact with an oxidizing agent as ferric chloride in a strongly acid solution it reacts with the N,N-dimethyl-p-phenylendiammonium ion to yield methylene blue.



N,N-dimethyl-p-phenylendiammonium — Methylene blue

Methylene blue is quantified by visible spectrometry.

Sampling rate

Sampling rate **Q** at 298 K (25°C) and 1013 hPa is **0.096 ± 0.005 ng·ppb^{-1}·min^{-1}**.

Effect of temperature, humidity and wind speed

Sampling rate varies from the value at 298 K on the effect of temperature (in Kelvin) as expressed by the following equation:

$$Q_K = 0.096 \left(\frac{K}{298}\right)^{3.8}$$

where Q_K is the sampling rate at the temperature K ranging from 268 to 313 K (from -5 to 40 °C).
Sampling rate is invariant with humidity in the range 10 - 90% and with wind speed between 0.1 and 10 m·s^{-1}.

Calculations

Once Q_K at the sampling temperature has been calculated, the concentration **C** is obtained according to the equation:

$$C = \frac{m}{Q_K \cdot t} 1{,}000$$

where **m** is the mass of sulphide ion in µg found onto the cartridge and **t** is exposure time in minutes.

Exposure

Exposure duration may vary from 1 hour to 15 days. Sampling is linear from 2,000 to 50,000,000 ppb·min of H_2S.

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Centro di Ricerche Ambientali - via Svizzera, 16 - 35127 PADOVA

Limit of detection and uncertainty

The limit of detection is 30 ppb for 1 hour exposure or 1 ppb for 24 hour exposure. The uncertainty at 2σ is 8.7% over the whole exposure range.

Storage

The cartridges are stable at least for 12 months before and 6 months after exposure. Do not expose all of the cartridges of the same lot: keep at least two of them as blanks.

Analysis

Reactives

ffi *sulphuric acid*: slowly add 25 ml of concentrated sulphuric acid to 10 ml water and let the solution cool;

ffi *amine*: dissolve 6.75 g of N,N-dimethyl-p-phenylendiammonium oxalate in the *sulphuric acid* solution. Dilute this solution to 1 liter with sulphuric acid - water 1:1 v/v. Kept in a dark bottle and well capped, this solution is stable for at least four weeks. **CAUTION**: this solution is very poisonous.

ffi *ferric chloride*: dissolve 100 g of ferric chloride hexahydrate ($FeCl_3 \cdot 6H_2O$) in 40 ml of water.

ffi *ferric chloride-amine*: mix 10 ml of *ferric chloride* solution with 50 ml of *amine* solution. This solution has to be freshly prepared;

ffi *sulphuric acid for dilution*: slowly dissolve 40 ml of concentrated sulphuric acid in 900 ml of water, let the solution cool and make up to 1,000 ml.

Procedure

Add 10 ml of water to the plastic tube containing the cartridge, recap and stir vigorously, preferably by a VORTEX stirrer.

Add 0.5 ml of *ferric chloride - amine* solution, recap **immediately** and stir. The tube must be capped immediately in order to avoid that the developed hydrogen sulfide can escape from the tube before reacting.

Wait for 30 minutes and measure absorbance at 665 nm using water to zero the spectrophotometer. The colour is stable for several weeks.

Do the same with two or three unexposed cartridges of the same lot and obtain the average blank value, then subtract it to the samples.

IMPORTANT

Absorbance is linear up to 1,200 absorbance units, corresponding to an exposure value of about 80,000 ppb·min. If higher absorbance values are obtained, dilute the samples with the sulphuric acid for dilution.

Be careful to apply the same dilution ratio to the samples and the blanks.

NEVER USE WATER TO DILUTE.

Calibration

Calibration curves may be prepared by sodium sulfide standard solutions, which have to be titrated just before use. As diluted sodium sulfide solutions are very unstable (the sulfide content can diminish as much as the 10% in an hour) it is strongly recommended to make use of the calibration solution code 171, following the instructions included.

USER TIP

Code 171 calibration solution relieves you from the task of preparation and titration of the sodium sulfide solutions.